Alternatives to Doing a Dam Thing

A Study of Options to Meet Raleigh's Water Supply Shortfall

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LIST OF ABBREVIATIONS

ACEP	Agricultural Conservation Easement Program
AF	Acre Feet
CDBG	Community Development Block Grants
cfs	cubic feet per second
CORPUD	City of Raleigh Public Utilities Department
CRS	Community Rating System
CWCB	Colorado Water Control Board
EIS	Environmental Impact Statement
EWPP	Emergency Watershed Protection Program
FEMA	Federal Emergency Management Agency
FMA	Flood Mitigation Assistance Program
HMGP	Hazard Mitigation Grant Program
mgd	million gallons per day
msl	mean sea level
NFIP	National Flood Insurance Program
OSHIT	Operational Supply and Hazard Integration Transfer pool
PDM	Pre-Disaster Mitigation
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WPFP	Watershed Protection Flood Prevention program
WRP	Wetland Reserve Program

ABSTRACT

Population projections for the City of Raleigh, NC indicate a shortfall in long-term raw water supply requirements given current service area demands. Raleigh is proposing the development of a new reservoir to meet midterm needs; however, the reservoir is a costly project with relatively short-term returns and is an environmentally sub-optimal solution. This report proposes four unique adaptive management options to Raleigh's existing reservoir, Falls Lake, as alternatives to a new reservoir: Permanent flood control pool reallocation, dynamic reservoir management, permanent sedimentation pool reallocation, and guide curve stabilization. Considering system risk, costs, ability to generate additional water supply, and environmental impacts, we recommend the combination of sedimentation pool reallocation and a flexible guide curve be explored to increase the city's water supply allocation from Falls Lake. Current static management of water supply sources is ill equipped to adapt to dynamic climatic conditions and human development which may lead to increased risk and vulnerability for the communities that rely on similar reservoirs for municipal water supply and flood control.

1.0 INTRODUCTION

American Rivers has engaged a team of graduate students from Duke University's Nicholas School of the Environment to assess the feasibility of several non-structural water supply alternatives for the City of Raleigh that minimizes environmental impact to natural river and wetland systems, alleviates projected raw water supply shortfall, and is compatible with multiple stakeholder objectives.

1.1 PROBLEM STATEMENT

The City of Raleigh Public Utilities Department (CORPUD) estimates that Raleigh will not have adequate water supplies in 2060 to meet projected population growth unless additional sources of drinking water are provided [1, 2, 3]. Average daily water demand for Raleigh and its merger partners is projected to increase by 51% to 65% by year 2030 and by approximately 122% over the next 50 years (Table 1). The City of Raleigh alone is expected to consume 37% to 50% more water by 2030 (Table 2).

Table 1. Service area average day water demand for Raleigh and Merger Partners (mgd)

Year	**Water Resources Assessment and Plan** [1]	**Little River EIS** [2]	**Water Quality Study and Master Plan Update** [2]	**Population and Water Demand Projections** [2]	**Triangle Regional Water Supply Plan** [3]
Current	51.9 (2011)	57.1 (2010)	58 (2010)	57.9 (2010)	52 (2010)
2020	64.4	76.5	77	74.3	69.9
2030	78.2	94.2	93.2	88.8	82.4
2040	91.3	N/A	N/A	N/A	92.3
2050	102.71	N/A	N/A	N/A	102.7
2060	115.0	N/A	N/A	N/A	115

Table 2. Service area average day water demand for Raleigh (mgd)

Year	**Little River EIS** [2]	**WQMP** [2]
2010	46.9 (2010)	45.7 (2010)
2020	58.4	54.8
2030	70.4	62.7

The City of Raleigh maintains three reservoirs for raw water supply: Lake Benson, Lake Wheeler, and its primary reservoir, Falls Lake. Excluding the 2007-2008 drought, the fifty-year safe yield for Falls Lake provides an annual daily average of 66.1 million gallons per day (mgd). Lakes Benson and Wheeler, part of the Swift Creek lake systems, supply an annual daily average of 11.2 mgd. Collectively, available surface water supply is 77.3 mgd [1]. While service area demand projections diverge somewhat, the consensus is that demand is expected to surpass supply by 2030 at the latest (Figure 1).

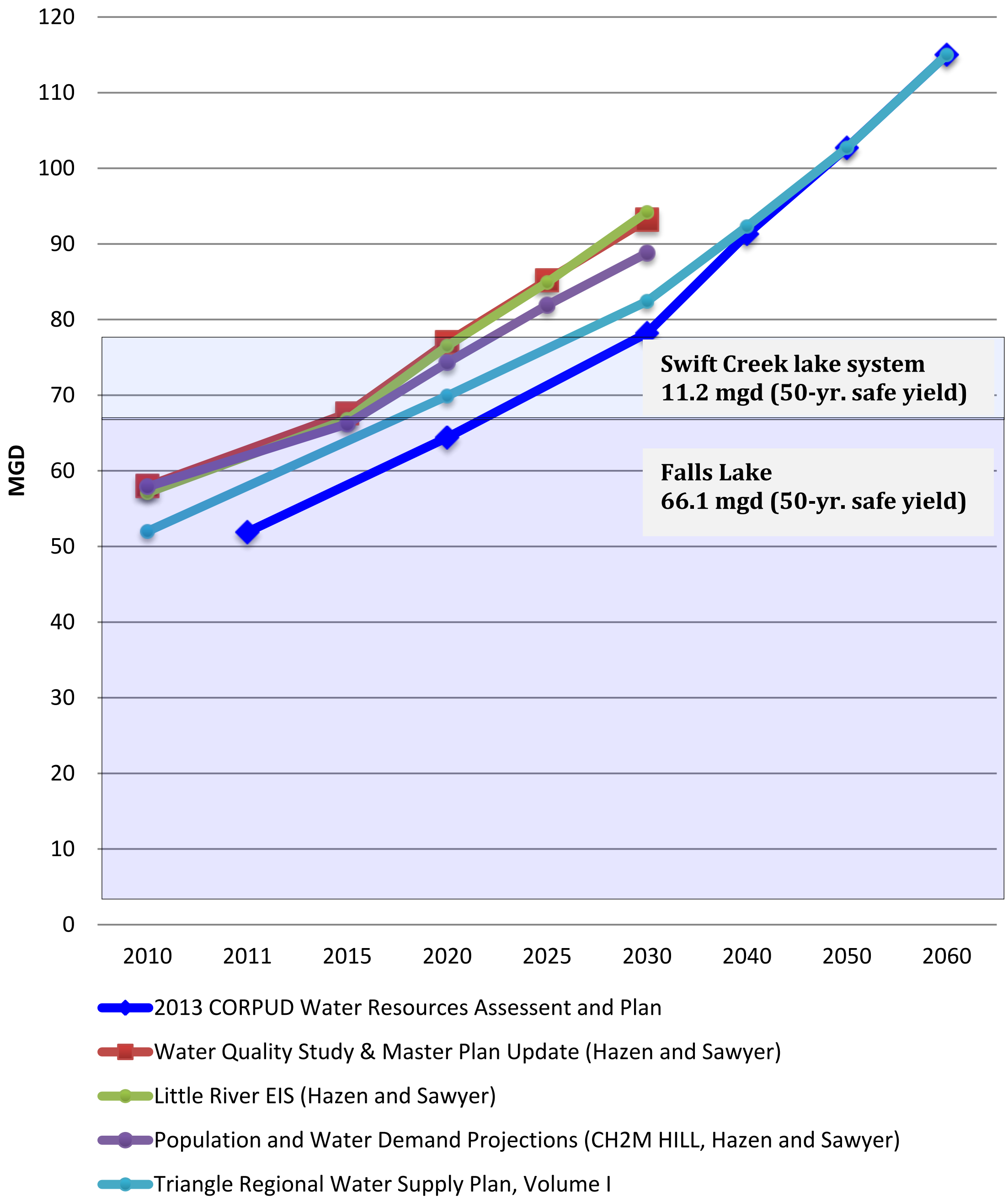


Figure 1. Average day water supply and demand projections for Raleigh and Merger Partners

1.2 POPULATION PROJECTIONS

Future service area demand calculations are contingent on several variables, a primary element being population projections. A significant increase in population can adversely impact water supplies in a number of ways. Rapid growth can extend service area demand past available water supply limits as well as strain the ability for local utilities to treat and deliver water. Additionally, city growth is usually accompanied by increasing numbers of development projects, landscape alterations, pollution, and industrial growth, all of which can impair water quality and affect the quantity of clean, available water.

Populations of interest for this report include the City of Raleigh, as the main consumer of water supplies, and counties upstream and downstream of the reservoir. Raleigh is considered one of the fastest growing cities in the United States [5,6]; Figure 2 indicates a 62% rise from the 2010 base year of study, and 147% from the 2000 U.S. Census Population Estimates [7].

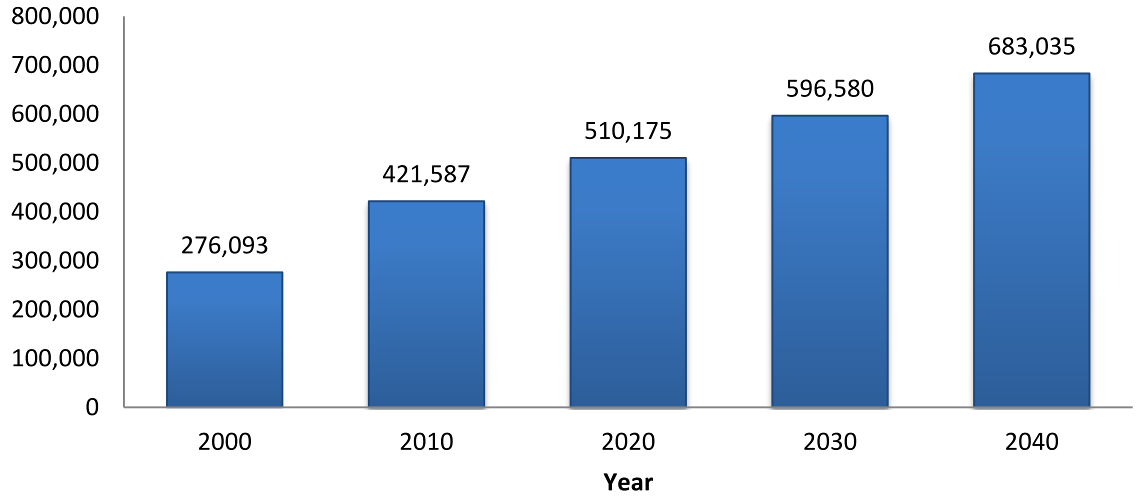


Figure 2. Raleigh population projections including extraterritorial jurisdiction and urban service areas

It is equally important to note population projections for counties upstream and downstream of the reservoir. Increased demands outside the service area may induce potential stressors for Falls Lake as these areas seek their own solutions to meeting water supply needs in the near future. The North Carolina Office of State Budget and Management projects an increase for most downstream communities, with Wake, Johnston, and Wayne counties growing by 17% to 53% by year 2033. Lenoir is the only county within the watershed expecting a slight population decline. Similar growth trends are visible in the upper watershed, with Durham and Orange County rising at the fastest speed (Table 3) [43, 51].

Table 3. County population projections in the upper and lower watershed

County	Population						Net Change
	2010	2015	2020	2025	2030	2033	
Durham	271,297	299,090	330,891	361,963	393,608	412,239	+52%
Granville	57,577	59,310	61,336	63,361	65,388	66,602	+16%
Johnston	169,632	181,192	191,886	202,583	213,275	219,695	+30%
Lenoir	59,406	59,380	59,379	59,381	59,380	59,381	-0.04%
Orange	134,302	144,855	155,337	165,888	176,427	182,751	+36%
Person	39,442	39,418	39,669	40,020	40,271	40,502	+2.7%
Wake	906,908	1,007,551	1,111,847	1,216,142	1,320,437	1,383,017	+53%
Wayne	122,845	127,958	132,277	136,596	140,916	143,506	+17%

1.3 CLIMATE VARIABILITY

Water utility operational decisions are dependent on weather information; thus, incorporating climate variability projections are critical in designing management strategies. The impacts of North Carolina climate variability on water supplies cannot be disregarded. Located in a region that is sensitive to naturally occurring weather oscillations and often a converging point for various meteorological patterns [15], the state is subject to severe weather impacts, the risk of which is greatly heightened when coupled with the effects of rapid population growth. North Carolina has experienced more weather-related disasters costing over a billion dollars than most other states within the past 30 years [12, 15].

Long-term, extreme weather trends as well as short-term variations that bring about high magnitude impacts affect the reliability of water supplies and can significantly decrease acceptable levels of service [9]. Increased storm severity and frequency, droughts, and extreme temperatures can impact water tables; hydraulics; increase treatment, maintenance, and operation costs; alter demand and strain distribution systems [9]. Planning with flexibility and foresight requires a nod to both historical data and climate projections that highlight disruptions to past, stable climate variations [10]. While constraints on historical trends are limited to data availability, future projections face numerous scientific uncertainties and a rapidly shifting knowledge base. Forecasts of climate change impacts vary and location-specific models are difficult to generate. However, federal and regional estimates agree on several broad changes for the Southeastern United States:

- Increasing inter-annual precipitation variability will lead to more frequent events of severe drought and rainfall conditions, particularly during the summer. While some studies indicate a clear increase in variability since the 1970s, other models tend to conflict or result in non-significant trends [13, 14].

- Decreasing water availability. Projections for the Upper Neuse River watershed indicate a 14% decrease in yield because of climate change. However, increasing Atlantic-basin hurricane intensity and frequency has been observed and is expected to continue [11, 15].

Climate projections face higher levels of uncertainty in regards to specific precipitation and runoff patterns [15]. In fact, the State Climate Office of North Carolina mentions that although increasing storm severity projections have been linked to the warming of the Atlantic Ocean, no significant drought or precipitation recurrence patterns emerge from their archives of weather data [9]. The Palmer Drought Severity Index for the Central Piedmont region of North Carolina indicate that highly variable precipitation patterns have been occurring since 1910 [18].

Despite these variations, many widely recognized sources consistently note that North Carolina has been and will continue to be subject to fluctuations between extreme wet and dry periods, with a future likelihood of increased swings in variability due to anthropogenic forcing [9,12,13,14,15]. Such events can yield substantial social and economic damage when considering the interaction effect of growing population and water demand. Substantial attention was garnered by both the 2002 and 2007 droughts in North Carolina, with the latter leaving Falls Lake reservoir just days away from running dry [13, 14]. Additionally, hurricanes such as Floyd and Fran incurred costly damages [11, 12]. In 1999, three hurricanes occurred within a 6-week period which led to records relatively similar to a 100- to 500-year flood event [16].

Such high-risk events require water resource management strategies that carefully consider options in light of projected climate variability. The utility of each project will differ depending on how well it responds to decreasing water yields and increasing flood risk. Managers challenged by limited funding should particularly look to the feasibility of a project to adapt to increasing weather fluctuations. Adaptation to climate variability can make communities less vulnerable to long-term changes should they arise [9,15]. Furthermore, these adaptive strategies could produce multiple co-benefits apart from increasing water supplies [15].

1.4 PROPOSED SOLUTION

Raleigh's impending shortfall has escalated the search for new raw water supply sources. CORPUD's proposed solution, identified as early as 1986 as a viable option [4], is construction of a new reservoir on Little River. The Little River Reservoir (we will commonly refer to it as Little River) is estimated to provide 13.7 mgd and include a 20 mgd water treatment plant [4]. Project completion is anticipated by 2020. A significant portion of property acquisition securing control for reservoir construction was completed by 2007 and wetland and stream delineations have also concluded, identifying 572 acres and 37,000 linear feet of impact [4]. Currently, the Little River Reservoir Project is in the Environmental Impact Statement review process.

The proposed Little River Reservoir is expected to provide a supply buffer that may last only two decades, given current consumption and projected requirements (Table 4). A relatively short-term return considering the cost to taxpayers is upwards of $350 million as well as the environmental degradation incurred by inundating acres of forested wetlands, miles of streams, and threatening a number of listed endangered species [8]. Even with inclusion of the Little River water treatment plant, the City of Raleigh and its merger partners are forecasted to run into another supply deficit by 2060.

Table 4. Projected demand and current supply

	2011	**2020**	**2030**	**2040**	**2050**	**2060**
Service Area Demand (mgd)	51.9	64.4	78.2	91.3	102.71	115.0
Surface Water Supply (mgd)	77.3	77.3	77.3	77.3	77.3	77.3
Total	+25.4	+12.9	-0.9	-14	-25.41	-37.7
Little River Reservoir – Future Supply (mgd) [4]	0	13.7	13.7	13.7	13.7	13.7
Total	+25.4	+26.6	+12.8	-0.3	-11.71	-24
Little River Water Treatment Plant – Future Supply [4]	0	20	20	20	20	20
Total	+25.4	+46.6	+32.8	+19.7	+8.29	-4

1.5 PROJECT PURPOSE

Building a dam and reservoir incurs substantial economic and environmental costs. The return on investment for Little River Reservoir appears low since the added supply capacity may only meet demand for two decades. The purpose of this report is to explore alternative options within the Falls Lake reservoir to determine if additional supply of 13.7 mgd or greater can be achieved in a cost-effective, politically viable and environmentally favorable way. If increased water supply from Falls Lake can be achieved, Little River can be shelved for the interim, allowing many more years for per capita demand reduction efforts, the advancement of reuse/recycling technologies and more precise estimates of long term population growth.

2.0 FALLS LAKE

2.1 CORPS RESERVOIR

Falls Lake is a federally owned water reservoir operated by the United States Army Corps of Engineers (hereto forward simply the Corps or USACE). Completed in 1983, the reservoir has authorized project purposes that include flood control, water supply, water quality, fish and wildlife, and recreation. The project is authorized by PL 89-298 (Public Law, 89th Congress, number 298) more commonly known as the Flood Control Act of 1965 (Title II) and the River and Harbor Act of 1965 (Title III) [23]. For this report, all values and figures for Falls Lake including elevations, acre feet (AF) stored, design, modifications and daily historical data have been retrieved from US Army Corps Falls Lake website under description of the project, pertinent data and historic information [24].

2.2 FALLS LAKE SPECS

Falls Lake became fully operational on December 7, 1983 when it reached full pool (lake surface) elevation of 250.1 mean sea level (msl). The lake at the guide curve covers an area of approximately 12,400 acres. The lake lies in Wake and Durham counties, extending 28 miles from the dam to the confluence of the Eno and Flat Rivers. Seven hundred and seventy square miles of the Upper Neuse drain to Falls Lake which augments flood flows downstream to Kinston, NC, a length of roughly 193 river miles. Modification of flows dissipates as distance downstream from the dam increases. Releases from Falls Lake to meet minimum flow requirements for fish and wildlife at the Clayton, NC gage are 254 cfs (cubic feet per second) from April to October and 184 cfs from November through March. Roughly 45,000 AF are allocated to water supply for the city of Raleigh. Another 61,322 AF are reserved for water quality and 25,073 AF for sedimentation. Together these three purposes contain 131,395 AF of storage at the guide curve, with 221,182 AF of empty storage reserved as controlled flood storage [24]. The maximum discharge at the dam through main outlet works is approximately 10,000 cfs. Once spillway elevation is reached (264.8 msl) the discharge increases to a max capacity of 39,500 cfs [25].

2.3 POOLS

The reservoir is divided into what are known as pools. Each pool of water, delineated by an elevation within the reservoir, holds water for different project purposes. Falls Lake has a bottom elevation of 200 feet above mean sea level. The sedimentation storage pool extends from 200 msl to 236.5 msl. This space has been reserved for sediment accumulation from inflows over the course of the reservoir's expected lifetime, approximately 100 years. The conservation pool extends from 236.5 msl to 251.5 msl. The conservation pool holds water for municipal supply (Raleigh), downstream water quality and for minimum flows for fish and wildlife in the Neuse River. Above 251.5 msl is empty storage for flood control. 251.5 msl to 264.8 msl is referred to as controlled storage as it contains all space in the reservoir from the top of the conservation pool to the crest of the spillway. Above 264.8 msl is uncontrolled flood storage, which is space above the spillway crest but retained behind the dam whose top elevation is 291.5 msl (Table 5). The division between the conservation pool and the flood control pool (in this case 251.5 msl) is called the guide curve or the rule curve, which will be discussed in detail in this report.

Table 5. Pool elevation and storage within Falls Lake

Pool	Acre Feet	MSL
Uncontrolled Flood	749,010	289.2
Controlled Flood	**221,182**	264.8
Water Supply	**45,000**	251.5
Water Quality	**61,322**	251.5
Sedimentation	**25,073**	236.5
Total Controlled	**352,577**	

Storage volumes were not readily available from USACE Wilmington District for Falls Lake. The shape of the storage curve was derived using a polynomial model fit between known storage values from 236.5 msl and 289.2 msl. The bottom of the lake (200 msl) was omitted from the model as it was interfering with accurately estimating the shape of the curve since slope at the bottom of the lake is effectively zero. Knowing the relationship between lake surface area and acre feet stored allows us to estimate increases in water storage from a marginal increase in surface elevation. Figure 3 displays additional water supply achieved at 0.2 foot increments of increasing lake level. Table 6 lists elevations and respective storage volumes between the 251.5 msl (the guide) and 253.5 msl. The equation estimated is:

$$y = 361.09x^2 - 169{,}440x + 20{,}000{,}000 - 94{,}199.95$$

Where y represents amount of water stored in acre feet and x is the elevation in feet.

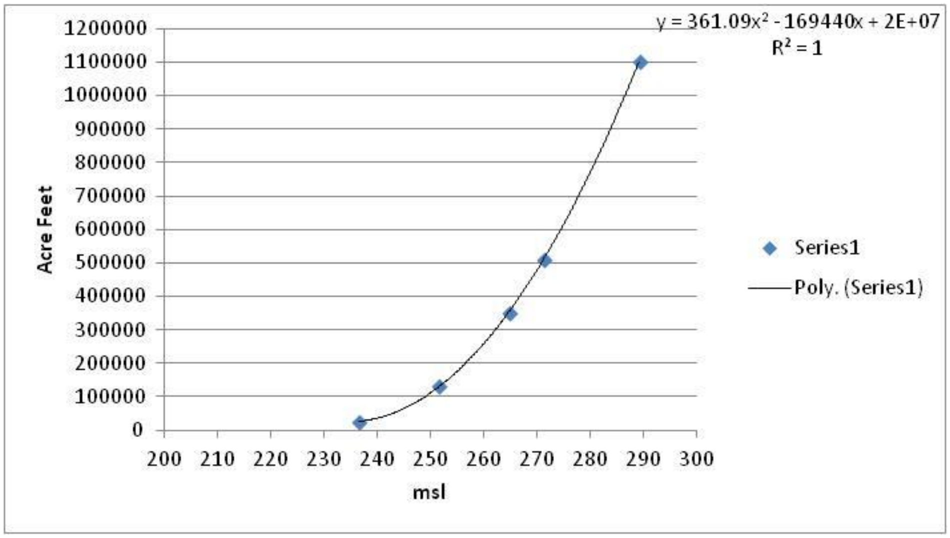


Figure 3. Elevation-storage curve

Table 6. Elevation-storage values

Elevation (Feet)	Total Water Storage (Acre Feet)	Added Water Storage (Acre Feet)	Additional Water Supply (MGD)	Elevation Increase (Feet)
251.50	131,395.00	-	-	-
251.70	133,847.10	2,452.10	2.19	0.20
251.90	136,328.08	4,933.08	4.40	0.40
252.10	138,837.95	7,442.95	6.64	0.60
252.30	141,376.71	9,981.71	8.91	0.80
252.50	143,944.36	12,549.36	11.20	1.00
252.70	146,540.89	15,145.89	13.52	1.20
252.90	149,166.31	17,771.31	15.86	1.40
253.10	151,820.62	20,425.62	18.23	1.60
253.30	154,503.82	23,108.82	20.63	1.80
253.50	157,215.90	25,820.90	23.05	2.00

2.4 GUIDE CURVE

A guide, or rule curve, is an elevation at which reservoir operators maintain a reservoir's surface level. For Corps projects like Falls Lake, the guide curve represents the top of the conservation pool which is a mixed use pool for water supply, water quality and minimum flows. Above the guide curve (beyond the top of the conservation pool) is the flood control pool. This space is generally kept empty and used in times of high inflow to retain floodwaters, preventing damage downstream of the reservoir. Therefore the guide represents the dividing line between water supply management and flood control management.

2.5 REALLOCATION

Reallocation is the act of repurposing a portion of water authorized for one purpose to another. Reallocation can take place within multi-use pools (i.e. water supply and water quality within conservation pool) or between pools (sedimentation and conservation). For instance water from the sedimentation pool may be reallocated to water supply, flood control space reallocated to the conservation pool, or a portion of the water quality pool reallocated within the conservation pool to water supply.

Authority to reallocate storage is derived in the Water Supply Act of 1958 [26] Reallocation is rare but not unusual for Corps projects. Past reallocations have been made for many different reasons affecting all pools. The process generally follows the path of reconnaissance, feasibility, and study. There is no established time frame for a successful reallocation, though they commonly require several years. The table in Appendix 1 lists all reallocations under the Water Supply Act of 1958 identified between the 1970s and the present.

As shown in Table 7, reallocation is not entirely objective. If a proposed reallocation is determined to cause a significant impact on a project purpose, it is the discretion of the agency to receive authorization from the Assistant Secretary of the Army, Civil Works or Congress. While reallocation of smaller quantities or percentages is feasible at a district level, requests are studied on a case-by-case basis and are highly subjective with determinations including increased flood risk, impacts on dam safety rating, minimum flows or water quality standards downstream.

As reallocation is based upon the maximum controlled storage of a reservoir, our percentages for Falls Lake will be based upon the top of the controlled flood pool at 264.8 msl with storage capacity of 352,577 AF.

Table 7. Threshold values for reallocation since at least the year 2000 [27]

Amount to be Reallocated	<499 AF	Up to 50,000 AF or 15% of Controlled Storage	>50,000 AF or 15% of Controlled Storage
Authorizing Entity	USACE District	USACE HQ	Assistant Secretary of the Army (Civil Works)
Congressional Approval	Only if project purpose severely impacted	Only if project purpose severely impacted	Only if project purpose severely impacted

3.0 INTRODUCTION TO OPTIONS

This report will specifically investigate options that require floodplain reconnection downstream and/or water reallocation within Falls Lake reservoir, altering reservoir management to increase system efficiency. Options discussed include:

1. Permanent flood pool reallocation with downstream floodplain management
2. Sedimentation pool reallocation
3. Accurate management to the current guide curve
4. Dynamic event management

We will discuss each option in terms of implementation practicability, additional water supply amassed, financial costs, environmental co-benefits, impacts on Falls Lake project purpose, risk to upstream and downstream communities, time frame, and overall feasibility. A synopsis of these evaluations is provided in The Matrix and Section 8.0: Comparison of Options, which frames the discussion of results as a comparison of implementation feasibility.

The City of Raleigh is exploring several other options to meet long term water supply requirements with the possibility of three additional sources of supply [28]. The options proposed in this document lay the groundwork for prioritizing nonstructural water management solutions early within the decision-making process.

4.0 PERMANENT FLOOD CONTROL POOL REALLOCATION / DOWNSTREAM FLOODPLAIN MANAGEMENT

Permanently reallocating space from the flood control pool would increase water supply at the top of the conservation pool in order to meet Raleigh's water supply shortfalls. The increased water storage in the conservation pool would reduce space in the flood control pool, minimizing the ability of Falls Lakes to control larger floods (such as a 100 – 500 year event). Therefore, there would be an increased risk to downstream stakeholders within the floodplain of more frequent land inundation during larger storm events. In order for this option to be successful, different programs and management strategies will be required to minimize the risk of flood damages and reduce the overall cost of potential increased floodplain inundation through easements, buyouts or flood proofing. Parcels falling within the 100 and 500 year floodplains in the three counties (Wake, Wayne and Johnston Counties) bellow Falls Lake were used to estimate the risk and cost of reduced flood control from the reservoir (Figure 4).

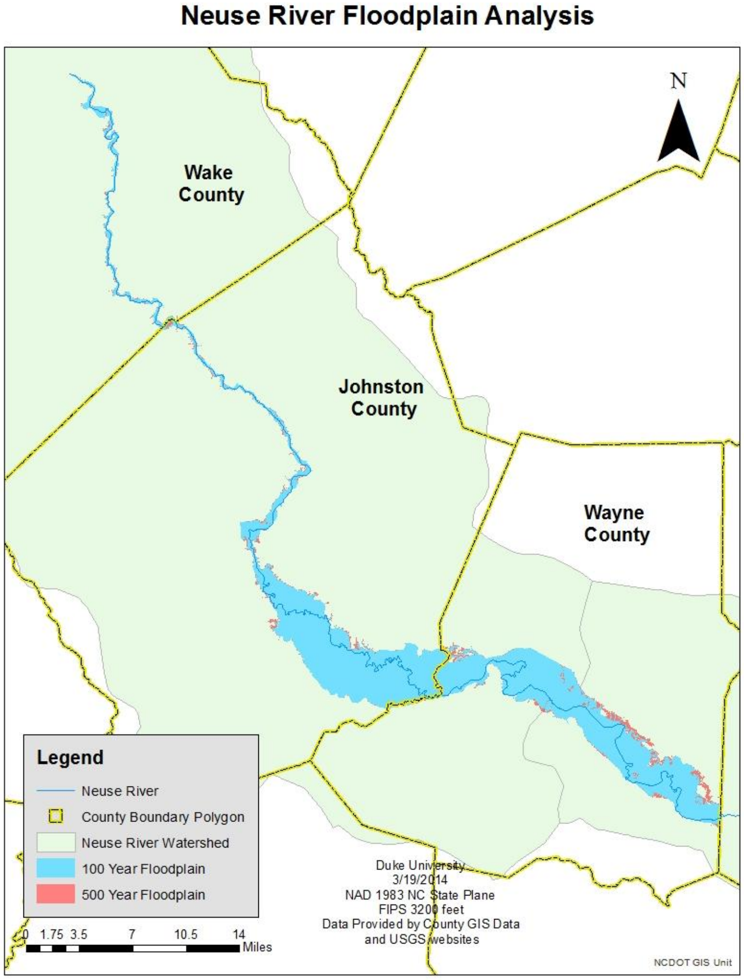


Figure 4. Project extent used to determine cost and feasibility of the permanent flood control pool reallocation option. Map includes the three counties analyzed as well as the 100- and 500-year floodplain extents.

4.1 PRACTICABILITY

Cost of floodplain management and the feasibility of reallocating space to the conservation pool determine if this option is practical. Based on our calculations it is possible to surpass Raleigh's water supply needs for 2060 with only a two foot reallocation. However, the potential cost of downstream floodplain management could make this option impractical. While cost limits this option, additional sources of funding can offset the total cost to less than that of the Little River Reservoir. With significant funding this option could be a viable source of water for Raleigh.

4.2 MODE OF IMPLEMENTATION

All reallocation decisions are at the exclusive direction of USACE. While there are thresholds in determining where reallocation decisions at Corps projects are made within the agency, it is not completely objective. If a proposed reallocation is determined to cause a significant impact on a project purpose (here flood control) it is the discretion of the agency to receive authorization from the Assistant Secretary of the Army of Civil Works or Congress. While reallocation of smaller quantities or percentages is feasible at a district level, requests are studied on a case-by-case basis and are highly subjective.

Our scenario seeks a reallocation of approximately 15,500 AF, or 1.25 feet/4.4% of flood control pool storage, which would require, at the minimum, authorization from USACE headquarters as it is greater than 499 AF and less than 50,000 AF/15% of controlled storage. However, if the additional elevation affected the dam safety rating (or similar), due to the communities downstream, it is likely that Congressional approval would be required.

For reallocation of flood control space it is highly likely that it is necessary to reduce risk downstream by managing the floodplain to a baseflood elevation significantly higher than the current 100 year rule. To do so, municipal and county governments would need to work with state and federal agencies to implement comprehensive mitigation efforts and new land use ordinances. Alternatively, USACE could attempt to increase the size of the floodway below Falls Lake by purchasing flowage easements on adjacent land to accommodate an increase in flood stage.

4.3 WATER SUPPLY

Increasing storage of the conservation pool is the most efficient method of reallocation as it provides the largest surface area, and therefore requires relatively small changes in elevation to accommodate large increases in water storage. A 1.2 foot increase at the top of the conservation pool would result in 13.52 mgd (15,145.89 AF) of additional water supply (Table 8). A two foot increase would result in an increase of 23.05 mgd (25,820.90 AF; methods for this option can be found in Appendix 2.1). Therefore, this option provides a permanent and high potential for additional water supply with minimal elevation increase to the conservation pool.

Table 8. Additional storage in mgd and AF for increases in the elevation of the conservation pool

Elevation (Feet)	Total Water Storage (AF)	Added Water Storage (AF)	Additional Water Supply (mgd)	Elevation Increase (Feet)
251.5	131,395.00	-	-	-
251.9	136,328.08	4,933.08	4.40	0.40
252.3	141,376.71	9,981.71	8.91	0.80
252.7	146,540.89	15,145.89	13.52	1.20
253.1	151,820.62	20,425.62	18.23	1.60
253.5	157,215.90	25,820.90	23.05	2.00
253.9	162,726.73	31,331.73	27.97	2.40

4.4 COSTS

The Flood Pool Reallocation/Floodplain Management option has the highest risk to downstream interests out of all options described in this document. Without altering floodplain management, the counties of Wake, Johnston, and Wayne have slightly over $676,000,000 worth of property within the 500 year floodplain and just under $500,000,000 within the 100 year floodplain. Seventy percent of the total cost to all three counties within the 500 year floodplain is from building parcels while the remaining thirty percent is associated with land value (Table 9; specific methods can be found in Appendix 2.2).

Table 9. Costs of land parcels and parcels containing structures within the 100 and 500 year floodplain for Wake, Wayne and Johnston counties

	Floodplain	Wake	Wayne	Johnston
Parcels with Only Land	**100 year**	$ 84,558,785.30	$ 56,074,381.31	$ 48,326,156.09
	500 year	$ 92,591,953.10	$ 60,223,601.14	$ 53,006,873.64
Parcels Containing Structures	**100 year**	$ 83,608,635.00	$ 197,941,526.00	$ 26,051,430.00
	500 year	$ 181,994,064.00	$ 235,553,546.00	$ 52,810,460.00
Totals	**100 year**	$ 168,167,420.30	$ 254,015,907.31	$ 74,377,586.09
	500 year	$ 274,586,017.10	$ 295,777,147.14	$ 105,817,333.64

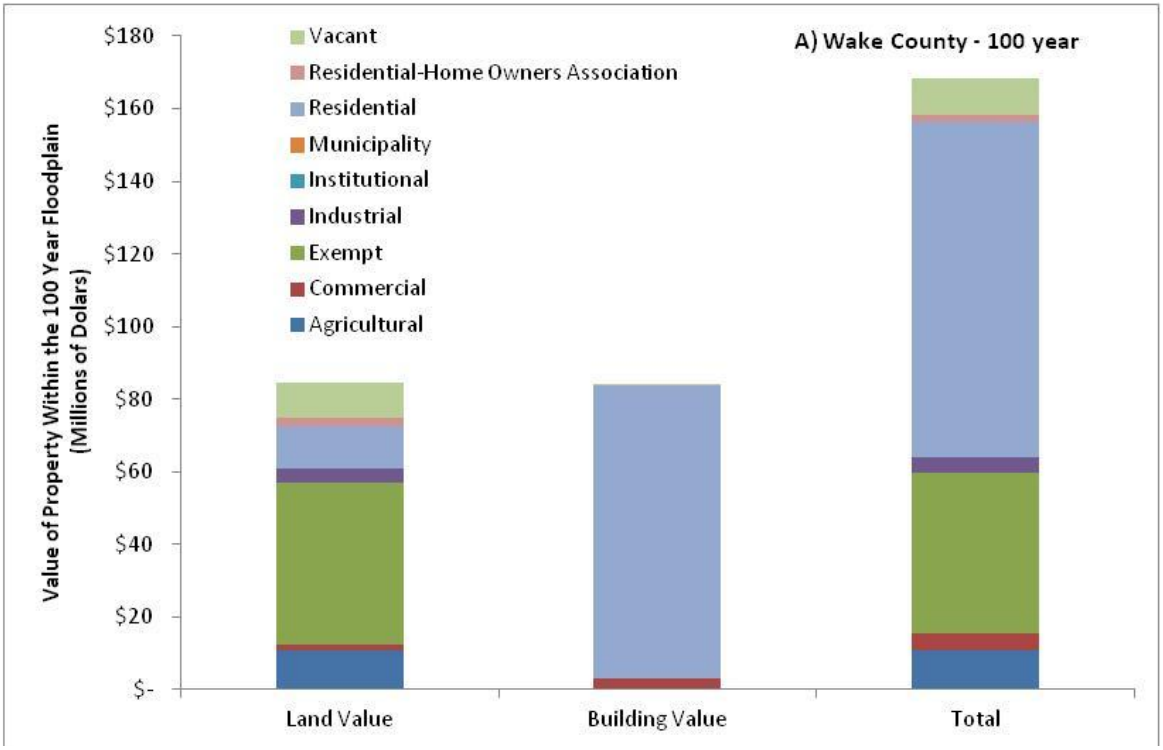
While the cost of damages in all counties is high, we assume that during most flood events not all of the property would be damaged. Table 9 provides an estimate of the highest potential cost of damages in the Upper Neuse Watershed during a 100 or 500 year storm. However, damage costs are expected to be slightly lower than the values presented in Table 9 as not all of the property would experience a total loss.

Wake County is closest to Falls Lake and therefore bears the highest risk of flood damages. However, the total cost of parcels within the 500 year floodplain is significantly larger than that of parcels within the 100 year floodplain (Table 9). This is due to fewer building parcels within the 100 year floodplain. Therefore, protecting land through easements or buyouts up to the 100 year floodplain would be most cost effective for Wake County. However, storms greater than a 0.01 recurrence interval would still incur large restoration costs.

Johnston County has the lowest potential cost within either floodplain. Additionally, the difference between the 100 and 500 year floodplains are very small (Table 9). Therefore, Johnston may be able to protect up to the 500 year floodplain with easements or buyouts for minimal costs.

Wayne County has the highest potential cost within either floodplain. Additionally, the cost of managing to the 100 year or 500 year floodplain is minimal (Table 9). This suggests that development is extensive within either floodplain and any management within Wayne County would be extremely costly.

Breaking down the cost estimate into land use could provide more detailed information about the risk with each county and provide information on the feasibility of managing to either floodplain. Residential land use accounts for 55 % of the total cost, and 48% of the building value within the 100 year floodplain (Figure 5A). Additionally, residential land use accounts for 67 % of the total cost in the 500 year floodplain (Figure 5B). Therefore, determining how to manage residential parcels should be a priority for Wake County. Additionally, there are 144 vacant parcels adding up to $9,900,000 in the 100 year floodplain and 218 vacant parcels costing $12,425,000 in the 500 year floodplain. These vacant parcels could be removed from the cost estimate. Additionally, parcels classified as exempt only have land within the floodplain and have a value of $44,358,000 in the 100 year floodplain, and $49,784,000 in the 500 year floodplain. If both exempt and vacant parcels were removed, the cost estimate could be reduced by 32.3% in the 100 year and 22.7 % in the 500 year. With these parcels removed from the estimate, the risk of flood in Wake County would have a maximum cost of $113,895,000 in the 100 year floodplain and $212,376,000 in the 500 year floodplain.



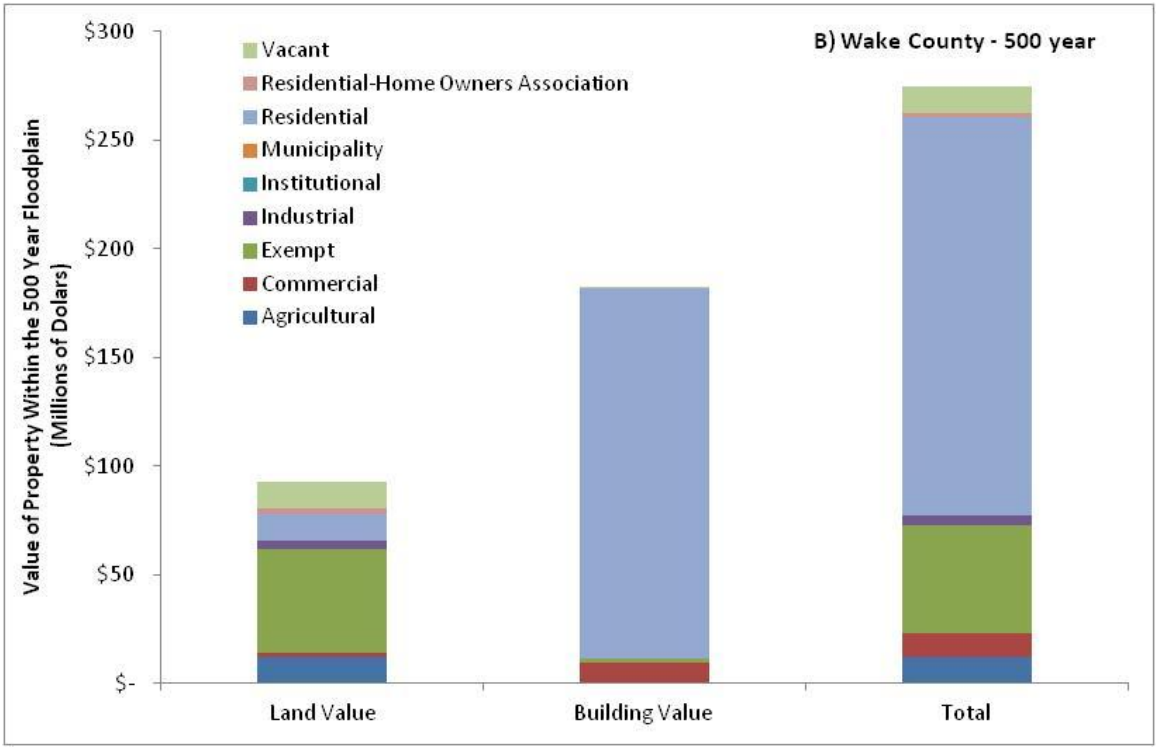
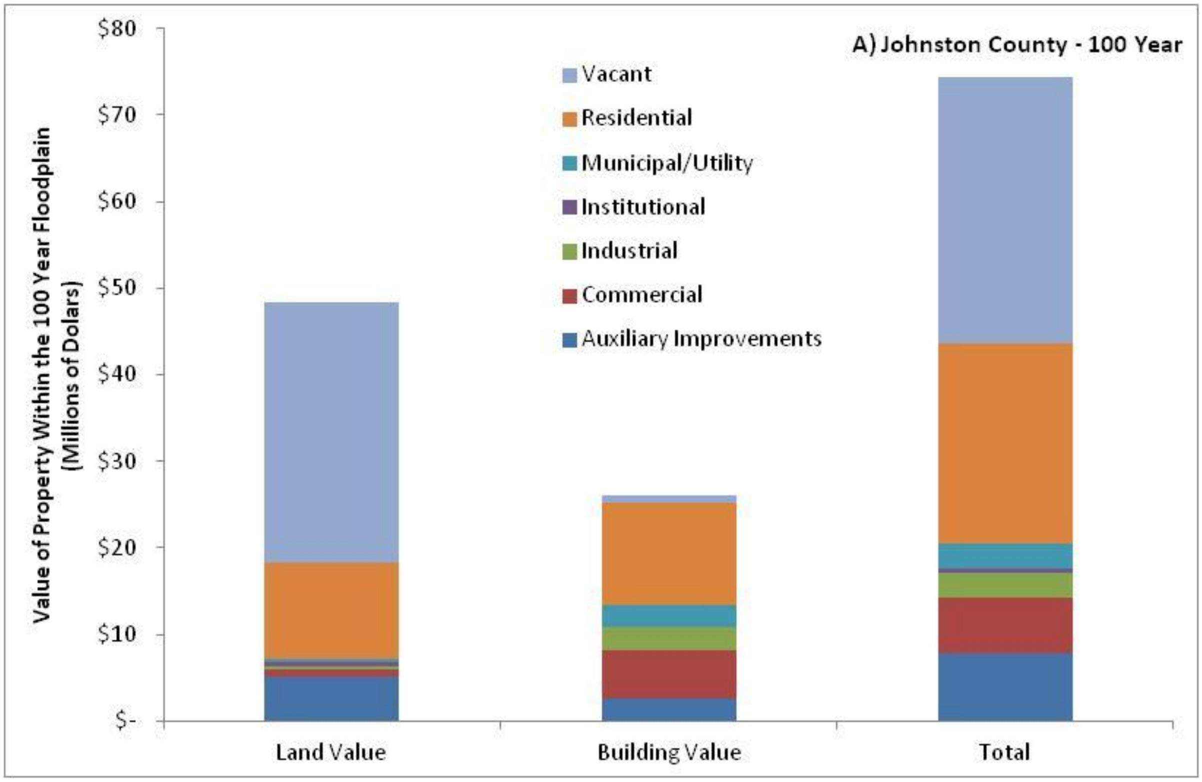


Figure 5A and 5B. Wake County property value separated by land use for A) the 100 year floodplain and B) the 500 year floodplain

The land value within the 100 or 500 year floodplain in Johnston County either outweighed or equaled the building value within the floodplains (Figure 6A, 6B). Specifically, in the 100 year floodplain a significant portion of the land value (41.4 %) is from vacant land use. By removing this land use from the estimate, the cost is reduced from $74,377,000 to $43,594,000. The 500 year floodplain in Johnston County is more heavily dominated by residential land use. However, by removing the vacant parcel value from the estimate, the cost would be reduced by $33,244,000 (31.4 %). Therefore, it could be cost effective for Johnston County to manage up to the 500 year floodplain through easements of buyouts with minimal cost.

As Wayne County did not provide land use codes for their parcel data a similar analysis could not be completed for that county. However, as our estimates include the city of Goldsboro we assume that most of the property value is attributed to residential, commercial or industrial land use.



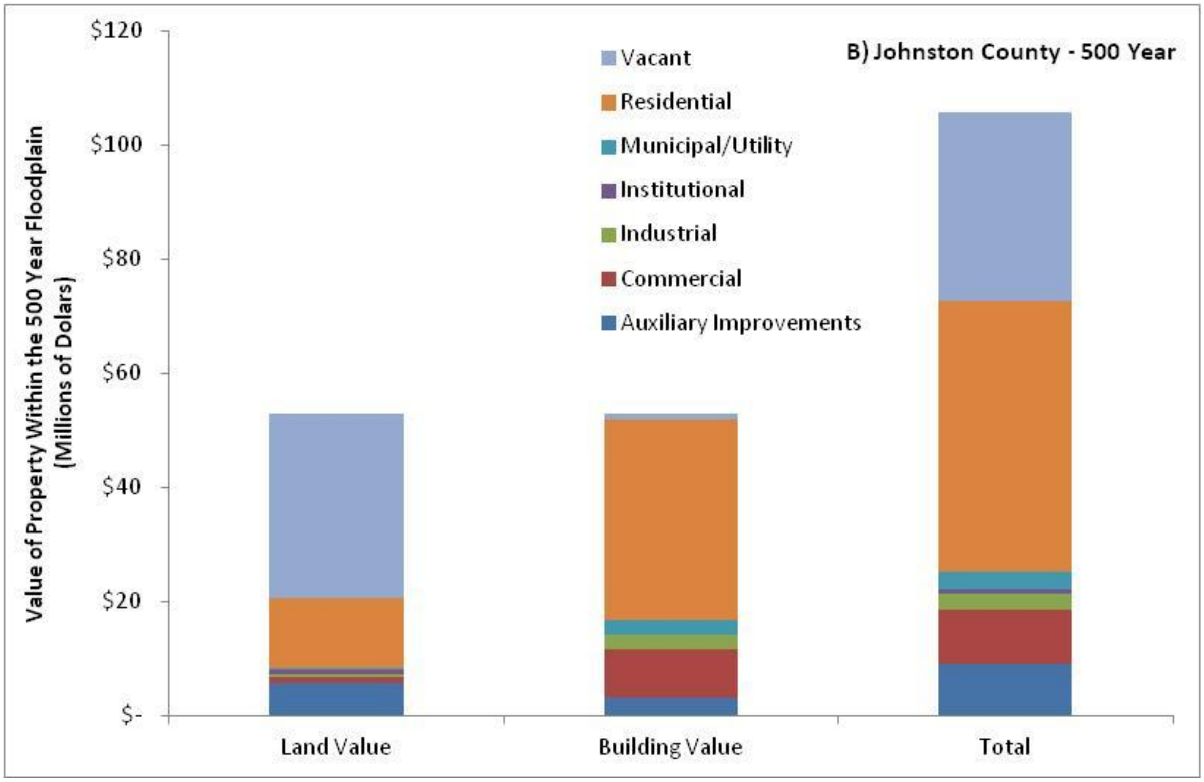


Figure 6A and 6B. Johnston County property value separated by land use for A) the 100 year floodplain and B) the 500 year floodplain

4.4.1 COST ASSISTANCE AND COST SHARING

The total valuation of all parcels in the three counties up to the 500 year floodplain is approximately $676,180,500, nearly twice as much as the expected cost to construct Little River Reservoir. Numerous, minimally overlapping federal cost-share programs exist related to proactive floodplain management. Table 10 summarizes the most relevant federal programs for our purposes. Even in a time of budget cuts and shrinking government services, these programs demonstrate that there is significant funding allocated annually that could be applied in the Neuse below Falls Lake.

Table 10. Federal flood mitigation programs

Agency	Program	Activity	Cost Share	Funding (2012) Million $
FEMA	PDM	Acquisition	75%	$ 35.5
FEMA	FMA	Acquisition	75%	$ 6.5
FEMA	CRS 520	Acquisition	CREDITS	$ -
FEMA	CRS 530	Floodproofing	CREDITS	$ -
NRCS	EWP	Flood Easements	75%	$ 235.4
NRCS	WPFP	Flood Easements	100%	$ -
USDA	WRP	Permenant Easements	95%	$ 430.0
HUD	CDBG	Acquisition	GRANT	$ 2,950.0

FEMA Hazard Mitigation Grant Program (HMGP): Funds local mitigation after events that trigger a nationally declared disaster. Local public entities may apply directly to FEMA or through their state (e.g. Office of Emergency Management). FEMA provides 75% of funding as a grant with the other 25% contributed locally or by the state. Funds may not be used from other programs to cover the local cost share.

FEMA Pre-Disaster Mitigation (PDM): Funding for local flood mitigation activities including acquisition, relocation and/or demolition. Monies are available to state and local governments. Local share is $0.25 for every $1 in funding.

FEMA Flood Mitigation Assistance (FMA): Funding for local flood mitigation activities including acquisition, relocation and/or demolition. Monies are available to state and local governments. Local share is $0.25 for every $1 in funding.

FEMA Community Rating System (CRS): A voluntary program that communities with National Flood Insurance Program (NFIP) policy holders may enroll. Activities under CRS generate credits to the community. Depending on the number of credits generated (for a wide variety of flood management/flood mitigation activities) private policyholders receive premium discounts of specific magnitude. Activities 520 and 530 in CRS are known as the buyout activities which include acquisition, removal and relocation.

NRCS Emergency Watershed Protection Program (EWPP)/Watershed Protection Flood Prevention Program (WPFP): Public and private landowners are eligible however a local (public) sponsor is required to make one eligible for most activities. Easements do not require a local sponsor. Program may be applied for pre or post disaster.

USDA Wetland Reserve Program (WRP): As of February 7, 2014 the WRP is expired and rolled in to the Agricultural Conservation Easement Program (ACEP). ACEP easements range from fixed term, to 30 years, to permanent. Grasslands, private forest lands, cropland and pasture are eligible for the program. ACEP is available directly to private landowners.

HUD Community Development Block Grants (CDBG): May be used for buyout and acquisition of low to middle income community properties. This program presents an opportunity for use in communities in the lower Neuse for individuals on marginal lands. It is a full grant program which represents free money to the local sponsors.

Several of the programs may only be applicable to a small fraction of the total area inside the 500 year floodplain. However, given the multitude of instruments, the high cost share of most programs and the savings to policyholders and local governments in NFIP/CRS communities, the cost of implementing our proposed 500 year management plan could be cut significantly. This value may approximate the cost of Little River Reservoir while solving two long term problems, water supply and flood damages.

4.5 BENEFITS

Distinct from the cost of acquiring, relocating structures and/or flood proofing within the 500 year floodplain are the long term avoided costs of managing to the 500 year while reducing flood control capacity of Falls Lake. Our hypothetical flood pool reallocation may significantly impact flood control along the Neuse from the dam to Kinston, where larger events would produce higher flood peaks downstream, with Clayton being a particular concern.

The Corps has estimated flood damages avoided by Falls Lake for each year since 1983. Values are estimates at five points below the dam. These estimates provide values for land and property damages had Falls Lake Reservoir not been there to act as a flood water detention basin, releasing flood waters once downstream gages fall below flood stage.

A complete table of annual estimated flood damages avoided can be found in Appendix 1. Table 11 below shows the summation of all five individual estimates for all years for the lower basin from Falls Lake to Kinston. Individual values are in dollars in the year of calculation and were present valued for the simple total below (in 2012 dollars). Additionally, the avoided estimates for the previous six years for each of the five reaches are found in Table 12. Again, estimates are in respective year dollars and have not been present valued.

Table 11. Flood damages prevented (1983-2012) [27]

Sum of Annual Estimated Flood Damages Prevented ($)	Sum of Annual Estimated Flood Damages Prevented PV 2012 ($)	Average Rate of Inflation (1983-2012)	Discount Rate (EIS)
$612,893,600	$1,066,372,287	2.94%	3.5%

Table 12. Flood damages prevented by reach (2008-2013) [27]

Reach	2008	2009	2010	2011	2012	2013	Total
Kinston	$9,000	$36,500	$749,200	$140,500	$0	$1,039,600	**$1,974,800**
Goldsboro	$771,600	$269,800	$1,066,100	$67,200	$0	$1,564,500	**$3,739,200**
Smithfield	$1,302,500	$52,200	$922,500	$79,700	$0	$2,684,300	**$5,041,200**
Clayton	$485,100	$7,300	$145,400	$3,700	$0	$264,000	**$905,500**
Falls	$83,100	$2,943,500	$18,349,700	$165,000	$344,200	$11,886,200	**$33,771,700**
Total	**$2,651,300**	**$3,309,300**	**$21,232,900**	**$456,100**	**$344,200**	**$17,438,600**	**$45,492,400**

Further evidence for the magnitude of benefits from avoided flood damages comes from three independent studies, summarized in a report by the American Institutes for Research for FEMA [28], examining gains to be had by modifying the existing NFIP standard 1% Rule [29]. First, USACE asked how losses would change if the NFIP standard was amended from 1% (100 year) to either 0.5% (200 year) or 0.2% (500 year). The survey estimated 43 river reaches in NFIP communities. The average ratio of avoided costs managed at the 500 year were found to be 2.24 times greater than the 100 year. The 200 year versus the 100 year was 1.48 times greater. Second, researchers using the HAZUS model selected river reaches approximating those in the USACE survey to recreate the initial findings. Their estimates of avoided costs were more conservative at 1.34 times greater in the 500 versus 100 and 1.11 times greater in the 200 versus 100. Lastly, University of Maryland Eastern Shore (UMES) repeated a similar study with river counties in Maryland and found the avoided costs of the 500 versus 100 to be 1.8 times greater [29]. It would appear that sampled rivers, and the communities along them, are highly heterogeneous and results are dependent on multiple factors. Table 13 below summarizes the results of the three studies.

Table 13. Ratio of avoided damage costs - hypothetical base flood elevation vs. 1% rule

Study	500/100	200/100	50/100
USACE	2.24	1.48	0.71
HAZUS	1.34	1.11	0.78
UMES	1.80	-	-
Average	1.80	1.30	0.75

A similar analysis would be required to determine the ratio of avoided damages in the Neuse Basin below Falls Lake to inform the magnitude of benefits in moving from the 100 year floodplain to the 500 year floodplain; and to compare against costs of a wide scale and comprehensive acquisition program. The efficacy of the permanent flood control pool reallocation relies on the benefits (as avoided damages) of incorporating fundamental changes in floodplain management.

4.5.1 CO-BENEFITS

Floodplain management presents a number of ecological co-benefits. The function of the Neuse River floodplain can be restored to some degree by managing to the 500 year floodplain. The power of the water within the river channel will be reduced if the water is allowed to inundate the floodplain during larger storms. With more frequent inundation of the floodplain, erosion within the channel is likely to be reduced. Fine sediments could be deposited along the floodplain, lowering the sediment load on the stream bed. This could create a rockier substrate which would generate more fish spawning habitat. Water quality, habitat, and ecological function are likely to increase if the Neuse River is managed to the 500 year floodplain. Not only would this provide downstream water quality and recreational benefits, this could reduce the potential need for stream restoration [29]. Further study would be required to substantiate the benefits noted above and to quantify the degree and impact of these ecological benefits.

4.6 PROJECT PURPOSE IMPACTS

The Permanent Flood Pool Reallocation/Floodplain Management option presents a fundamental change from a flood control purpose to a priority on water supply in Falls Lake. Additionally, this option puts residents within the downstream floodplain at risk of flooding. Therefore, we assume that the Corps will have a low interest in this option. USACE would prefer to manage Falls Lake for the original flood control design and alterations in that management would have a low feasibility of success.

4.7 RISKS

The risks associated with the permanent flood pool reallocation option are similar to the cost analysis. If downstream floodplain is not managed or only managed to the 100 year floodplain there is high risk of flood damages during larger storm events. However, it is likely that these risks would diminish after the adoption of floodplain management up to the 500 year floodplain.

4.8 TIME FRAME

This option would require a full study prior to reallocation. This study could be longer than twelve years [30] as the reallocation would need to consider the dam safety rating to incorporate a raise in the conservation pool [31]. Additionally, downstream floodplain management would take several years before completion. Therefore, this option would not be able to provide additional water supply to Raleigh for a decade or more until studies and floodplain management to mitigate risk are completed.

4.9 FEASIBILITY

The Permanent Flood Pool Reallocation/Floodplain Management option has a relatively low feasibility of success. Without additionally funding the cost of downstream floodplain management could be between $500 and $675 million, and even with additional funding could cost well above the estimated cost of Little River Reservoir ($300 million). Additionally, this option requires a significant change in the operation of Falls Lake from flood control to water supply. Not only would USACE oppose this alteration, CORPUD would have a low interest in this option if Wake County decided to manage to the 500 year floodplain. Floodplain management in Wake County would be extremely costly for CORPUD. However, if Wake County was not required to increase downstream floodplain management because the risk of holding more water in Falls Lake was considered to be lower than the cost of managing to the floodplain, CORPUD may be very interested in this option as the cost would be drastically reduced. Unlike USACE, FEMA would be very interested in this option as it would provide an opportunity to introduce alternate floodplain management strategies downstream of Falls Lake and avoid future disaster assistance payments after losses. For example, this option provides a further incentive to implement the NFIP Community Rating System (CRS) which could lead to innovative, more cost effective floodplain management. Finally, downstream interests may have two different views to this option. First, they may focus on the increased flood risk to their property and therefore have a low interest in this option. This view may be specifically pertinent for homeowners closer to the Neuse River in Wake County. However, an alternative view is that the communities within the floodplains could receive funding for floodplain management. Therefore, the federal money provided for flood protection could offset the fear of increased flood risk.

However, this option does have the greatest potential for water supply and the most co-benefits through avoided flood damages. Despite the potential advantages of this option, it is not cost effective, would take an extremely long time to implement, and requires changes to a major project purpose of Falls Lake.

5.0 SEDIMENTATION POOL REALLOCATION

Sedimentation pool reallocation requires the permanent transfer of storage volume from the sedimentation pool to the water supply pool. It is an option that has been mentioned in Falls Lake North Carolina Management plans as early as 2008 [32]. The John Redmond reservoir in Kansas has employed a relatively similar method of reallocation and a temporary sedimentation pool reallocation has previously been approved in the neighboring Cape Fear Watershed [33]. As part of the 2008 Jordan Lake Drought Contingency Plan, USACE was given authority to facilitate emergency transfers from the sedimentation pool during severe dry conditions based on the Flood Control Act of 1944 [33].

Although this option is feasible, management considerations for this alternative will likely focus on costs, which can become substantial if increased sedimentation requires large-scale or constant dredging operations and sediment disposal. Another concern is whether congressional authorization is required as mentioned in the 2013 Water Resource Assessment and Plan [1]. The water supply section below indicates that reallocation amounts are below the 50,000 AF and 15% of total storage capacity limits that would require congressional approval. Agency discretion can be used providing that some conditions are met [27, 34].

5.1 PRACTICABILITY

The principal factors concerning the practicability of sedimentation pool reallocation are two-fold. First, an accurate assessment of the surplus storage volume and sediment characteristics is necessary. Secondly, a permanent reallocation requires confident projections on the growth of sedimentation rates to ensure that infilling does not lead to subsequent storage deficits during the timespan of the project. The data for Falls Lake indicates that the sedimentation pool is currently well below capacity and historical trends point to far lower sedimentation rates than what the reservoir was designed to hold [35].

5.2 MODE OF IMPLEMENTATION

The sedimentation pool was originally designed to hold 25,073 AF of storage, which allows for a sedimentation rate of approximately 0.33 AF per square mile of drainage area per year over the 100-year lifespan of Falls Lake reservoir [36]. To date, there have only been three sedimentation rate studies conducted by either USGS or USACE. Each study concluded that sedimentation rates have not exceeded the threshold for maximum sediment accumulation.[35] Prior to the construction of the reservoir, USGS estimated a sediment rate of 0.07 AF per year per square mile of drainage area [37]. Since 1976, sedimentation ranges on the Falls Lake project have been obtained through two studies: The original pre-impoundment survey in 1982 and a resurvey in 1997 [35]. The resurvey results document a net sediment accumulation of 10,913 AF throughout the reservoir (190-290 msl). The 1997 study, however, is inconsistent with baseline data, citing an overall increase in reservoir capacity within the fifteen year gap between the two studies. Resurvey data shows that the sedimentation pool alone had grown in storage capacity from 25,069 to 25,793 AF, and that the average sedimentation rate within the 15 year period was -728 AF per year or -0.95 AF per year per sq. mi. of drainage area [35]. This result is unlikely, and the resurvey report refers to differences in data coverage, technological advances in data collection, and other potential errors to explain the net increase.

Sedimentation pool reallocation relies on available space in Falls Lake's sedimentation pool, which lies below elevation 236.5 msl [36]. Although the 1997 resurvey claims a total capacity increase in sediment storage from 25,069 to 25,793 AF, a closer look at the elevation intervals show that sediment accumulation is greater in the lower half of the sedimentation storage pool. Resurvey data shows a total sediment deposit of 201 AF below elevation 220 msl, the breakdown of which are as follows:

- Elevations 190 to 200 msl contain 4 AF of storage and are entirely filled with sediment
- Elevations 200 to 210 msl have decreased to half its initial capacity
- Capacity within elevations 210 to 220 msl has been reduced by 2%
- Sediment loss (storage capacity increase) begins at 220 msl and above [35].

5.3 WATER SUPPLY

Based on the 1997 resurvey and current USACE storage volumes for Falls Lake, the sedimentation pool has 24,872 AF of available capacity out of a total storage volume of 25,073 AF. This volume is equivalent to 8,104.6 million gallons or 22.2 mgd.

Understanding future capacity would require an updated resurvey on sedimentation rates and ranges, taking into account projected land use change, expected development impacts, erosion patterns (particularly in eroding uplands), and climate change impacts on erosion due to storm intensity and frequency. Assuming an annual sediment accumulation of 0.33 AF per sq. mile drainage area (254.1 AF) for the remainder of project life, available sedimentation storage capacity will decrease from 24,872 AF to 13,183 AF by 2060. Higher and lower bounds indicate adjustments due to gradually increasing or decreasing rates (Figure 7). Information concerning the chosen sedimentation rate and parameters on sensitivity analysis are discussed in Appendix 3.

Three levels of reallocation are applied based on availabilty projections. A 25%, 50%, and 90% transfer from the sedimentation pool to the conservation pool would achieve an additional 5.5 mgd (6,218 AF), 11.1 mgd (12,436 AF), and 20 mgd (22,385 AF) respectively if current availabiility is 22.2 mgd (24872 AF) (Table 14). These projections are all based on the sedimentation rate of 0.33 AF per year per square mile drainage area. Neither the USGS 1976 survey nor the 1997 resurvey reported sedimentation rates as high as those in our projections. If future analysis indicates significant downward trend in sedimentation rates, more water could be available for potential reallocation.

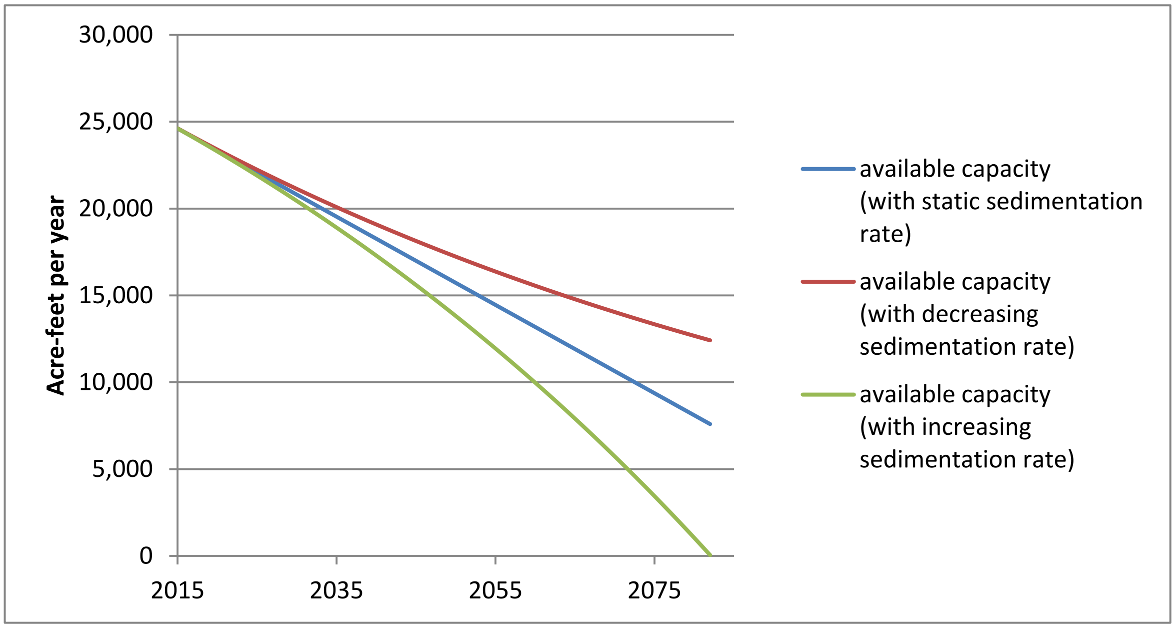


Figure 7. Decreasing sediment storage capacity over project life

Table 14. Potential reallocation amounts based on sedimentation rate changes

Year	Availability based on static sedimentation rate (mgd)			Availability based on decreasing sedimentation rate (mgd)			Availability based on increasing sedimentation rate (mgd)		
	25%	*50%*	*90%*	*25%*	*50%*	*90%*	*25%*	*50%*	*90%*
2014	5.5	11.1	20.0	5.5	11.1	20.0	5.5	11.1	20.0
2030	4.6	9.3	16.7	4.7	9.4	17	4.6	9.1	16.4
2060	2.9	5.9	10.6	3.5	7	12.5	2.2	4.4	8

5.4 COSTS

Any reallocation would require a reconnaissance phase, feasibility phase, and finally approval as discussed in earlier sections. The reconnaissance phase for a current water quality reallocation request will cost $500,000 [38]. We assume that reconnaissance for a sedimentation request would be approximately equal to that of the current request. The reconnaissance phase will require a sedimentation resurvey for Falls Lake. Recent sedimentation resurveys at W. Kerr Scott reservoir in Wilkes County, NC in 2010 cost $113,187 [39]. Feasibility phase costs are unknown. However, costs will be incurred by the Corps or cost-shared according to the Water Resources and Development Act of 1986, depending on whether congressional authorization is needed for reallocation [38]. The most recent Corps reallocation at Chatfield Reservoir in Colorado cost $5.8 million to create a joint flood control-conservation pool with 50/50 cost share [30]. We would anticipate similar costs for a sedimentation pool reallocation at Falls Lake.

Should initial or intermittent dredging be required, it would increase the implementation and monitoring costs substantially. The City of Raleigh and Raleigh Public Utilities would bear the costs of dredging. Dredging costs vary significantly depending on area size and whether the removal process requires hydraulic or mechanical dredging. Dredging companies within North and South Carolina provide 2012 cost estimates ranging from $14-$55 per cubic yard, with one estimate as high as $100 per cubic yard [40]. Sediment removal at Brown’s Cove on Lake Wylie cost Mecklenburg County $20.75 per cubic yard. The total expected cost for 15,000 cubic yards was $311,250 [8]. A sedimentation pool reallocation from John Redmond Reservoir in Kansas predicted dredging costs of $49 million to restore 8,275 AF of storage [41].

Land use best practices can be employed to reduce the need for dredging if infill rates remain low or in addition to dredging as cost mitigation. Strategic implementation of sedimentation buffers, municipal codes for facilitating low-impact development, and other similar practices can minimize management risk and better predict sedimentation rates. Higher confidence can allow for larger percent transfers of storage.

5.5 BENEFITS

A foreseeable benefit is a marginal improvement in water quality in the Neuse if stormwater best management practices or restoration efforts are implemented in conjunction with, or as opposed to, any necessary dredging. If application of this option required effective sediment and erosion control, then a synergistic effect may remove a sizeable amount of phosphorous, nitrogen, and other pollutants from the Neuse River [42].

5.6 PROJECT PURPOSE IMPACTS

This option has no significant impacts on the current Falls Lake project purpose of flood control or other project purposes. Since sedimentation pool reallocation does not require any alterations to the top of the conservation pool or guide curve, there is no effect on flood storage space or dam safety rating.

5.7 RISKS

We perceive three manageable risks in sediment pool reallocation. First, the most recent sedimentation study for Falls Lake is dated and data quality needs further substantiation. If inaccurate, there may be less space available than previously thought or sedimentation rates may be less overestimated than previously believed. Second, it is possible that future growth and development upstream may significantly increase sedimentation into Falls Lake, altering the capacity available for reallocation. Each county within the Upper Neuse Watershed is expected to experience population growth between 2010 and 2033 [43]. Third, Falls Lake may not be able to meet its water quality rules if more water is used for municipal supply. This risk could be addressed with investment in neighboring communities’ wastewater treatment plants and through work with landowners and communities upstream to reduce stormwater runoff and decrease impervious surfaces. Compared against the other options, sedimentation pool reallocation poses medium-level risk as sedimentation rates are easier to monitor, forecast, and projection errors will not immediately impact users downstream or upstream.

5.8 TIME FRAME

The time frame for sediment pool reallocation is approximately 5 to 8 years, with a majority of time spent in the reconnaissance and feasibility phases. Our time frame estimations are based on a similar reallocation from the John Redmond Reservoir, KS which took eight years for reallocation but experienced significant delays due to levee safety issues [41]. Sediment pool reallocation could potentially have the shortest time frames out of all of the proposed options.

5.9 FEASIBILITY

Reallocation is of significant interest to USACE, CORPUD, City of Raleigh, and the State of North Carolina. Sediment and erosion control can also fall under the purview of NC Division of Land Management. Judging by its appearance in several NC management plans, it may be less controversial for Falls Lake whether as a permanent or short-term solution [1, 32, and 33].

Advantages to consider with this option is the potential to provide the 13.7 mgd generated by Little River, depending on actual storage availability, infill rates, and whether dredging and sedimentation control is employed. Costs can also vary significantly depending on how the option is implemented and maintained. Lastly, the project offers multiple environmental co-benefits, which translate into potential health or passive use benefits from marginal improvements in water quality downstream.

No serious effects on downstream users are expected, aside from potentially high amounts of suspended sediment concentrations resulting from dredging operations that increase turbidity and temperature. These effects may disturb aquatic environments for some distance downstream. Upstream considerations could be significant if the City of Raleigh decides to assign fees or prohibit future development to protect the watershed.

One main disadvantage is the presence of endogenous risks involved in managing sedimentation rates to increase water supply. Such risks include population growth and climate variability, which affect all options including Little River reservoir. More concrete baseline data and resurvey information can strengthen projections and better inform decision makers about the feasibility of using this option through the end of the project.

6.0 SEASONAL GUIDE CURVE

A seasonal adjustment to the guide curve (top of the conservation pool) would provide additional water supply by capturing high volume spring inflows and operating the reservoir at a higher elevation. The marginal change in elevation would determine the additional water supply with an increase of 1.25 feet yielding approximately 14 mgd. The higher lake level would correspond to the period of the year with relatively low flood risk or extreme event activity. The reservoir would then be drawn down during the summer months through when Raleigh's water demand is approximately 20% higher than annual average and evaporation rates are highest. There would be minimal overlap with the period of highest flood risk (August-October) at which point the reservoir will have drawn down to below the existing guide of 251.5 msl.

6.1 PRACTICABILITY

Implementing a seasonal guide curve for Falls Lake would require the raising of the conservation pool above the current ceiling at 251.5 msl. Pool raises are constrained by the Dam Safety Action Classification (DSAC) which is an overriding factor for all reallocation studies in which pools are raised [31]. Currently Falls Lake operates with a DSAC rating of III (on a scale of I-V). As of January 2013 USACE does not permit reallocations for DSAC I, II and III dams. Dams with a rating of IV are considered on a case by case basis. For this option to be considered the Falls Lake DSAC rating would need to be downgraded to IV.

6.2 MODE OF IMPLEMENTATION

The DSAC rating is dependent largely on the risk that the dam poses combining probability of failure, loss of life, economic and environmental risks. Targeted acquisitions in Wake County and Clayton (Wayne County) may allow for the DSAC rating to be downgraded. Alternatively, as we are proposing a seasonal guide, the safety or risk of the dam differs over the course of the year. That is, the highest risk to the dam and downstream communities is in the late summer and early fall with occurrence of Atlantic hurricanes; whereas we propose to increase the guide during a period of lower risk. It is unlikely that the Corps would consider a seasonal DSAC rating even with evidence of temporal differences in risk.

6.3 WATER SUPPLY

We estimate that a seasonal guide curve would provide additional water supply between 11 and 25 mgd. The amount of water is dependent upon the change in elevation and could range from zero (0 foot increase in the guide) to the top of the controlled flood storage pool at 264.8 msl. For our purposes, and attempting to propose a practicable solution, we have bounded the increase in the guide from 1 foot to 2 feet (252.5 msl- 253.5 msl) corresponding to increases in supply of 11-25 mgd.

6.4 COSTS

Without information available on similar seasonal guide curve studies we estimate the costs of this option to be in line with the costs of a recent joint pool reallocation at Chatfield Reservoir in Colorado. This yet to be finalized reallocation created a dual pool of conservation for municipal and industrial water supply and flood control. The cost was $5.8 million with a 50/50 cost share between the Corps and Colorado Water Control Board (CWCB) [30].

6.5 BENEFITS

As the reservoir would simply change its existing elevation by some marginal amount, without affecting other aspects of operations, we do not anticipate any co-benefits resulting from a seasonal guide curve.

6.6 PROJECT PURPOSE IMPACTS

The existing guide curve of 251.5 msl is based upon the original structural design of the dam, underlying soils and geology, historical climatic and geo-physical data, and land surveys among other factors. Raising the guide would reduce existing and designed flood control space by some amount. The degree to which flood control operations would be impacted depends upon the increase in the guide. Two further points: First, a re-survey 15 years ago found errors in the original mapping and the guide curve was subsequently increased from 250.1 msl to 251.5 msl in the year 2000 [27]. There is a possibility that that latest survey contains errors to be corrected in the future. Second, in casual discussions with USACE [27] we were told that the reservoir is not actively managed to the guide curve; and in fact fluctuations in lake level around the guide of a couple feet are not a concern. We are lead to believe that impacts to flood control would be minimal.

6.7 RISKS

The main risk of a seasonal guide curve is to flood control operations. Mentioned above, any increase in guide decreases controlled flood space. Our seasonal guide would be in effect during the portion of the year with lowest flood risk. Large and even extreme events are still possible though unlikely.

It is possible that population growth and/or water demand will proceed faster than projected. If a seasonal guide curve was implemented with a minimal amount of additional supply, under the above scenario, Raleigh would be forced to find an additional water supply solution on short notice.

6.8 TIME FRAME

If recent pool raising reallocations are used as an indicator, we would anticipate a seasonal guide curve for Falls Lake to take up to 12 years to complete [30]. The time frame would be much less if the DSAC rating was lower, but downstream risk mitigation must happen first so we would expect the process to last in to the next decade.

6.9 FEASIBILITY

Without a change in the DSAC rating the feasibility is low to none. In their planning bulletin issued January 11, 2013 USACE stated, “DSAC I, II and III: Reallocation that requires raising the conservation pool will not be permitted” [31]. It is unknown what precipitated the update; however pressure has been growing in recent years for the Corps to reallocate water within federal reservoirs to municipal and industrial supply [44].

With a change to DSAC IV (low urgency) from DSAC III (moderate urgency) a seasonal guide would be far more probable. Again, a combination of factors contributes to the DSAC rating, but a targeted removal of human and economic risk from the system downstream is critical to the option's feasibility.

7.0 DYNAMIC EVENT MANAGEMENT

Falls Lake reservoir is a multiple use facility with a major project purpose of flood control. This reservoir has traditionally had a static management style in which water is stored during the winter and spring when there is consistent inflow with low risk of large flashy storms. This water is drawn down during the summer months due to water withdrawal for Raleigh and evaporation. During the hurricane season (August – October), the reservoir lake levels is lower which provides empty space in order to control larger flood events (Figure 8). However, the period of lowest storage in Falls Lake also correlates with the highest water demand from Raleigh.

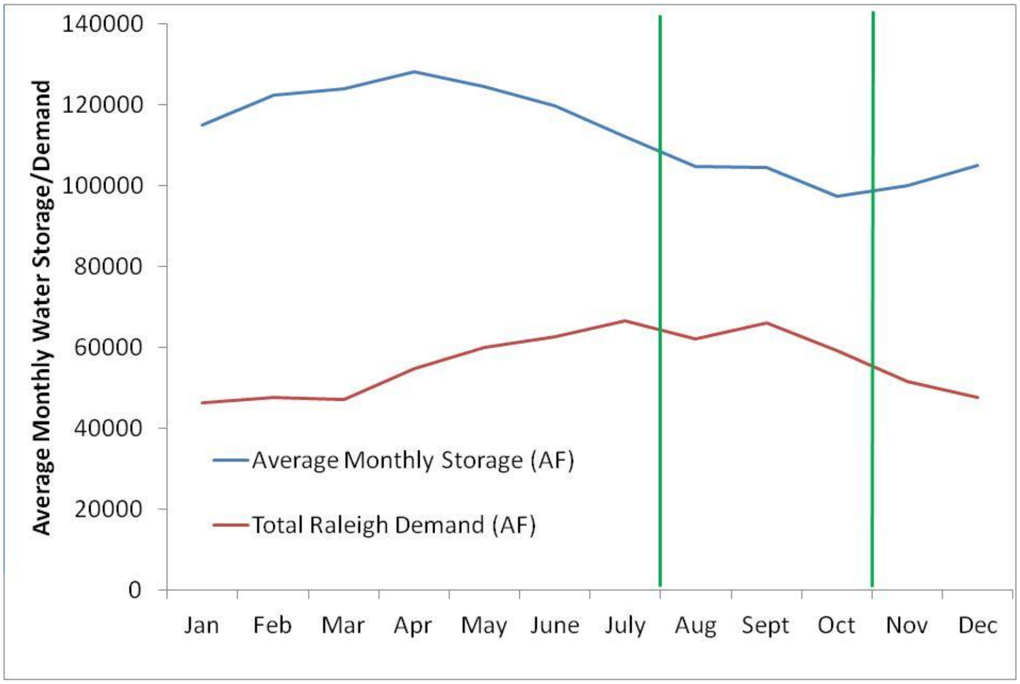


Figure 8. Average monthly water storage of Falls Lake, and total monthly water demand from Raleigh (AF)

Dynamic event management would permanently create the Operational Supply and Hazard Integration Transfer (OSHIT) pool, a joint purpose pool of 13.7 mgd above the guide curve, to provide additional water supply for Raleigh. During the hurricane season when reservoir lake levels would normally be lowest, the reservoir would maintain its additional water supply unless a large storm or hurricane was predicted. If that hurricane was predicted the additional water supply from the OSHIT pool would be released prior to the storm event in order to provide enough flood control space.

7.1 PRACTICABILITY

The additional stored water in the OSHIT pool would need to be released with enough time to allow the Neuse River to return to base flow at Kinston prior to the storm event. If there was not adequate time to allow for the river to return to base flow, the release from Falls Lake could induce flooding along the Neuse River, particularly in Clayton.

In order for this option to be practical, storm and hurricane forecasting must be accurate up to at least 4.5 days in advance (results for this option are available in Appendix 5.2. This amount of forecast time would allow the Neuse River at Kinston to fall back to base flow after a release of 13.7 mgd at 6,000 cfs from Falls Lake. Methods for determining prediction time can be found in Appendix 5.1.

7.2 MODE OF IMPLEMENTATION

In order to implement the dynamic event management there would need to be a joint reallocation from the flood control pool and the conservation pool. This joint reallocation could be modeled after the reallocation at Chatfield Reservoir, CO [30]. When there is little risk of storms the joint reallocation area could be kept full for water supply and periodically drawn down if a storm was predicted. If a storm were predicted we would assume little demand for water in the days prior to the hurricane and the event would help replenish the reservoir to its previous storage. Implementing a joint reallocation would require approval by the USACE headquarters and potentially congressional approval depending on the percentage of space reallocated and the impact on flood control operations.

7.3 WATER SUPPLY

The dynamic event management option would only provide 13.7 mgd based on our analysis. While there is the potentially to joint reallocate more space than an additional 13.7 mgd, the forecast time would increase above 4.5 days creating even more risk to flood control or water supply.

This option would provide the same amount of water supply as Little River Reservoir without any additional infrastructure. However, similar to the issues with Little River Reservoir, 13.7 mgd would not be enough to completely meet Raleigh’s water demands for 2060. Therefore, additional sources of water would need to be secured prior to 2060 even if this option were implemented.

7.4 COSTS

As this option is similar to the recent joint pool reallocation at Chatfield Reservoir, CO we estimated that the costs would be relatively similar. The reallocation of ~12 feet of elevation to allow for conservation for municipal and industrial water supply and flood control cost ~$5.8 million with a 50/50 cost share between the US ACE and Colorado Water Control Board (CWCB) [30]. As the dynamic event management option in Falls Lake would reallocate less than two feet, we estimate that the cost may be less than that of Chatfield Reservoir.

7.5 BENEFITS

There are minimal potential co-benefits from the dynamic event management option. One potential co-benefit is that the periodic flood pulses from Falls Lake reservoir could mimic more natural systems [29]. However, additional research would be necessary to determine if these flood pulses have a positive environmental effect on the system.

7.6 PROJECT PURPOSE IMPACTS

The dynamic event management option would require Falls Lake to increase the value of water supply compared to flood control. Falls Lake would be required to alter their reservoir operations prior to storms to provide the necessary flood control. By also providing water supply throughout the hurricane season, Falls Lake runs the risk of flooding parcels downstream of the reservoir if storms are not accurately predicted. Therefore, the USACE may oppose this option as it does present the possibility of reducing Falls Lake's ability to control floods.

7.7 RISKS

This option has the highest risk out of any of the options presented in this document. If the Neuse River is not at base flow prior to a storm event, travel times may be decreased because Falls Lake would have to discharge less to avoid inducing a flood in Clayton. Additionally, this option would require reservoir managers to accurately know when a storm is going to hit and the magnitude of the storm at least 4.5 days in advance. If those estimates are incorrect, there is a high risk of water supply shortage (if the storm is smaller than anticipated or changes course) or increased flood damage (if a storm is not forecasted four days in advance).

While our work shows that it is possible to use dynamic management as an operations tool, the Corps has expressed that the degree of uncertainty and risk to downstream communities makes it highly unlikely to be placed into practice. We agree that our dynamic option would operate with a high degree of uncertainty and without perfect information; however, we believe there is more risk to water supply, rather than flood control operations. If water is flushed through the system below bankfull (top of the river bank where it connects to the floodplain) volumes, before a hypothetical hurricane, it should not cause damage. If the hurricane changes course, and anticipated inflows do not materialize, the reservoir has now been drawn down during a period of high water demand.

A second argument made by the Corps is that flood risk would be increased by operating the reservoir at a higher level because the facility was engineered to withstand specific tolerances, given certain upstream and downstream, physical and geo-physical constraints. However, as we have demonstrated in our earlier seasonal guide option- with potentially the most important assumption, the reservoir's design- inflow from upstream has decreased dramatically since 1974. Climatic variability, human development and water supply demand have altered what was assumed constant. The disparity between long term reservoir level and flood risk is growing through the interactions of these variables. Static management works in a static world; but as we understand our world and requirements to be dynamic our management should reflect that change.

7.8 TIME FRAME

Based on the time frame observed in the joint reallocation in Chatfield Reservoir, CO [30], and given the need to downgrade the DSAC rating, we would anticipate 12 years or longer implementing our dynamic event management option. Initially a joint reallocation study would need to be conducted in order to determine if this option would be feasible and that would require several years to complete. After completion of the study implementation of the option may take a number of additional years for flood mitigation efforts on the Neuse floodplain downstream of Falls Lake.

7.9 FEASIBILITY

The dynamic event management option has a relatively low feasibility of implementation. While this option is much less expensive than the Little River reservoir, it still can only provide 13.7 mgd which is not enough to meet Raleigh’s raw water requirements for 2060. Additionally, this option has the highest potential risk of downstream flooding or drought conditions due to inaccuracies in storm forecasting. The high risk and uncertainty associated with this option would make it relatively infeasible with the USACE. Also, this option would require a change in reservoir management to prioritize water supply at the expense of flood control. This option has a relatively low feasibility because of the minimal water supply, change in project purpose, and extremely high risk.

8.0 COMPARISON OF OPTIONS

8.1 WATER SUPPLY

The permanent flood pool reallocation option provides the most stable source of water up to 23 mgd. This is provided by raising the guide curve by two feet of elevation. The sediment pool reallocation has a similar potential for water supply ranging from 5.5 to 20 mgd. While this is not as large as the permanent flood pool reallocation option, it is equally, if not more stable because that water already exists within the reservoir. The seasonal guide curve also has a high potential of providing up to 25 mgd. However, due to high demand and evaporation during the summer months it is unlikely that reservoir lake levels would be able to reach an increase of 25 mgd without raising the guide curve during the winter and spring. Finally, the dynamic event management option would only be able to provide 13.7 mgd, the same amount as the Little River Reservoir. Similar to the issue of Little River, the dynamic event management option would fall short of Raleigh’s 2060 water supply requirements. Based on our analysis, the permanent flood pool reallocation option and the sediment pool reallocation options would provide a stable source of water which exceeds the requirements of Raleigh.

8.2 COSTS

The permanent flood pool reallocation option has the highest cost due to downstream floodplain management. While the cost varies depending on additional sources of funding, it could be far more expensive than that of the Little River Reservoir estimated at $300 million. The costs of all of the other options are based on values from the recent study at another USACE facility, Chatfield Reservoir, in Colorado. Due to the necessity of additional research and analysis all three of the other options would cost over $ 5.8 million. While this is a rough estimate, these options would be far less expensive than the permanent flood pool reallocation option or the Little River Reservoir because they would require no additional infrastructure. Therefore, we would expect the seasonal guide curve, dynamic/event management, and sediment pool reallocation option to be at least and order of magnitude smaller in cost than Little River. However, downstream floodplain management/protection may be required if any of the options effect the DSAC rating. If floodplain management is required in any of the options, the cost would be expected to increase exponentially.

8.3 BENEFITS

The permanent flood pool reallocation option has the most co-benefits through avoided flood damages. By flood proofing or buying land in the most vulnerable locations (closest to Falls Lake and in Clayton), the cost of direct property damage, business interruption, non-market damage, human loss, and emergency response could be reduced. Dynamic event management may also have some co-benefits through flood pulses restoring more natural stream function to the Neuse River. However, all of the two other options have no major co-benefits. Therefore, the permanent flood pool reallocation option has the highest potential of additional benefits.

8.4 PROJECT PURPOSE IMPACTS

The sediment pool reallocation option has no effect on the project purpose as it would not significantly alter the storage within Falls Lake. Therefore, the reservoir could continue operating as a flood control reservoir while providing enough water supply to Raleigh. The permanent flood pool reallocation option would require a change in reservoir operations from focusing on flood control to focusing on water supply. This change most likely would be infeasible with USACE and therefore reduces the overall probability of implementing this option. The seasonal guide curve also may pose a threat to the project purpose as it would require more water storage in the reservoir than previously observed. While the lake level would not exceed the guide curve, managers would need to air on the side of water supply rather than flood control. Dynamic event management also could have some impacts on project purpose due to the potential risk of inaccurate storm predictions. If a storm were not accurately predicted, Falls Lake could have to release its additional water supply during a hurricane which would induce flooding downstream of the reservoir. Also, if a storm changed course within the four day window it would result in drought conditions. Therefore, the dynamic event management option runs the risk of impacting the project purpose by not providing enough flood control or by not having enough water to meet Raleigh’s raw water supply requirements.

8.5 RISKS

The dynamic event management option has the highest potential risk out of all of the proposed options. Depending on the downstream Neuse River level prior to a storm event or inaccuracies in storm prediction, Falls Lake could create flooding conditions during a storm or drought conditions. The flood pool reallocation option also has risks from potential increased flooding prior to managing to the 500 year floodplain. However, despite the risk associated with the permanent flood pool reallocation option, it is still potentially less than that of dynamic event management. The seasonal guide curve and sediment reallocation options have minimal risks. The seasonal guide curve option could create downstream flooding if the current guide curve is incorrect. Additionally, the sediment pool reallocation option would be at risk of increased sedimentation rates due to upstream development. The seasonal guide curve and sediment reallocation options would be the most feasible due to their low associated risks.

8.6 TIME FRAME

Sediment pool reallocation has the shortest time frame for implementation as it does not involve raising the conservation pool. By altering the conservation pool or guide curve there could be complications with flood control operations and the dam safety rating which could dramatically increase the time frame for reallocation. Additionally, as there would be no need for downstream land acquisition and no impact on Falls Lake project purpose, the sediment pool reallocation would require the shortest time necessary to do a preliminary study for implementation. This option could be completed within 5-8 years where as all of the other options could take between 5 to 15 years to implement.

8.7 FEASIBILITY

The sediment pool reallocation option would be the most feasible option to implement based on the combination of assessed criteria. This option has a high potential for water supply (up to 20 mgd) at a fraction of the cost of Little River Reservoir or the permanent flood pool reallocation option. Additionally, sediment pool reallocation poses no change in the project purpose, could be available in 5-8 years, and has minimal risks.

The three other options presented rely on a change in the DSAC rating or a revision in Corps policy for reallocation involving pool raises. Assuming the rating of Falls Lake could be downgraded to DSAC IV from DSAC III, the seasonal guide curve would be the second most feasible option to sediment pool reallocation. Similar to the sedimentation reallocation option it provides high water supply (up to 25 mgd) for minimal cost or risks. However, this option does pose some changes in the project purpose. Additionally, the water supply may not be stable due to variable inflows, especially during the summer months.

Dynamic event management has a medium to low feasibility rating due to its high risks and potential impacts on project purpose. Additionally, this option would not be able to meet Raleigh’s 2060 water requirements as it could only provide the same amount of water as Little River Reservoir (13.7 mgd).

Finally, the permanent flood pool reallocation option has the lowest feasibility. While this option also has the potential of providing a stable water source and co-benefits through avoided flood damages, the cost is greater than that of Little River Reservoir. Therefore, economically this option would be infeasible as an alternative plan to the proposed reservoir.

9.0 STRATEGY RECOMMENDATIONS FOR AMERICAN RIVERS

9.1 SEDIMENTATION POOL REALLOCATION STUDY

Based upon our analysis and comparison of options we recommend immediate action to begin a sedimentation re-survey and reconnaissance for reallocation from the sedimentation pool to the conservation pool. Sedimentation reallocation has the highest probability of implementation by USACE while achieving a volume of supply equivalent to that of Little River to meet midterm water demand.

9.2 DSAC RATING ANALYSIS AND EVALUATION

The overriding factor for immediate implementation of our three other options is the current USACE policy of no pool raises for projects with DSAC ratings of I-III [31]. More knowledge is required on how the rating system operates and the criteria and weights for different indicators of risk. Ultimately any reallocation or significant change in operations at Falls Lake will need to address the DSAC rating and achieve a IV.

9.3 STRATEGIC ACQUISITIONS IN HIGH RISK AREAS

Known factors contributing to the DSAC rating, as well as current flood control operations at Falls Lake, include the extent of persons and property within the floodplain downstream. The town of Clayton among other sensitive and high risk areas will require flood mitigation efforts to facilitate a change in DSAC rating and increase the feasibility of USACE allowing a seasonal guide curve. Additional study should be performed to identify if flowage and/or conservation easements are feasible or if more aggressive fee-title buyout of property is required.

9.4 POLICY WINDOW FOR PROGRAMMATIC/COMPREHENSIVE ACQUISITIONS

If catastrophic events similar to those of 1996 and 1999 repeat there may be a window to undertake large scale buyouts basin wide. Communities in the Lower Neuse used buyouts effectively in the wake of Hurricane Floyd. With assistance and political will from the State government, forward planning, and the economic-spatial detail presented within this report an opportunity exists to fundamentally change the management of floodplains in the State of North Carolina, similar to the move in Easton, PA to the 500 year floodplain after catastrophic flooding [58]. As we have evidenced in this report, proactive floodplain management provides strong economic and social benefits [66] while minimizing the disparity between managing reservoirs for flood control and water supply.

10.0 MANAGEMENT RECOMMENDATIONS FOR USACE

10.1 DATA COLLECTION AND MANAGEMENT

During the study period we uncovered deficiencies in essential information for optimal management of Falls Lake. A study on the sedimentation rate for the reservoir is required every 15 years. The last study, in 1997, showed a net export of sediment from the reservoir, casting doubt on the validity of the results [35]. The results of the 1997 study suggest that another survey should have been conducted but was never initiated. The subsequent sedimentation survey scheduled for 2012 but has not been commenced to this date.

The avoided damage cost estimates from Falls Lake provided by the Corps were valuable for estimating the benefits from hypothetical changes in floodplain management practices. Corps cost estimates are made in each of five downstream reaches and summed to get an annual lower basin avoided damage cost. While the basin wide totals were available for all years, reach damages were only available for 2008-2013 due to the misplacement/loss of earlier estimates. The lack of this information hindered our floodplain analysis and ability to prepare more precise estimates within the basin. Additionally, this insufficient data will prevent similar future studies.

Daily data is available for Falls Lake operations and provides details on reservoir levels, storage, discharge, water supply withdrawal and other metrics. However, one important measurement, inflow, is produced as a net value from changes in other parameters. There are no inflow gages on the tributaries feeding the reservoir. Instead inflow data is calculated from reservoir storage changes and estimated evaporation rate. The estimated inflow data can reduce the accuracy of analyzing the effects of seasonal trends, climate change, and land cover change on inflow variability. More precise inflow data is necessary and could be provided by investment in gaging systems on the major tributaries to Falls Lake (Eno River, Little River, Flat River, and Ellerbe Creek) to monitor and evaluate changes within the watershed.

10.2 ACTIVE MANAGEMENT

Falls Lake operations should modify its management plan to incorporate the thirty years of daily climate data, upstream land use change trends, water consumption trends, and population growth. It is ineffective to operate at a status quo and not consider activity and new information in operating procedures.

Similarly, intra and inter year climate projections and weather forecasts continue to become more refined. Incorporating such probabilistic models, with reasonable uncertainty, in to an adopted active planning process for reservoir operations would yield more efficient operations.

10.3 INCREASED ADAPTABILITY

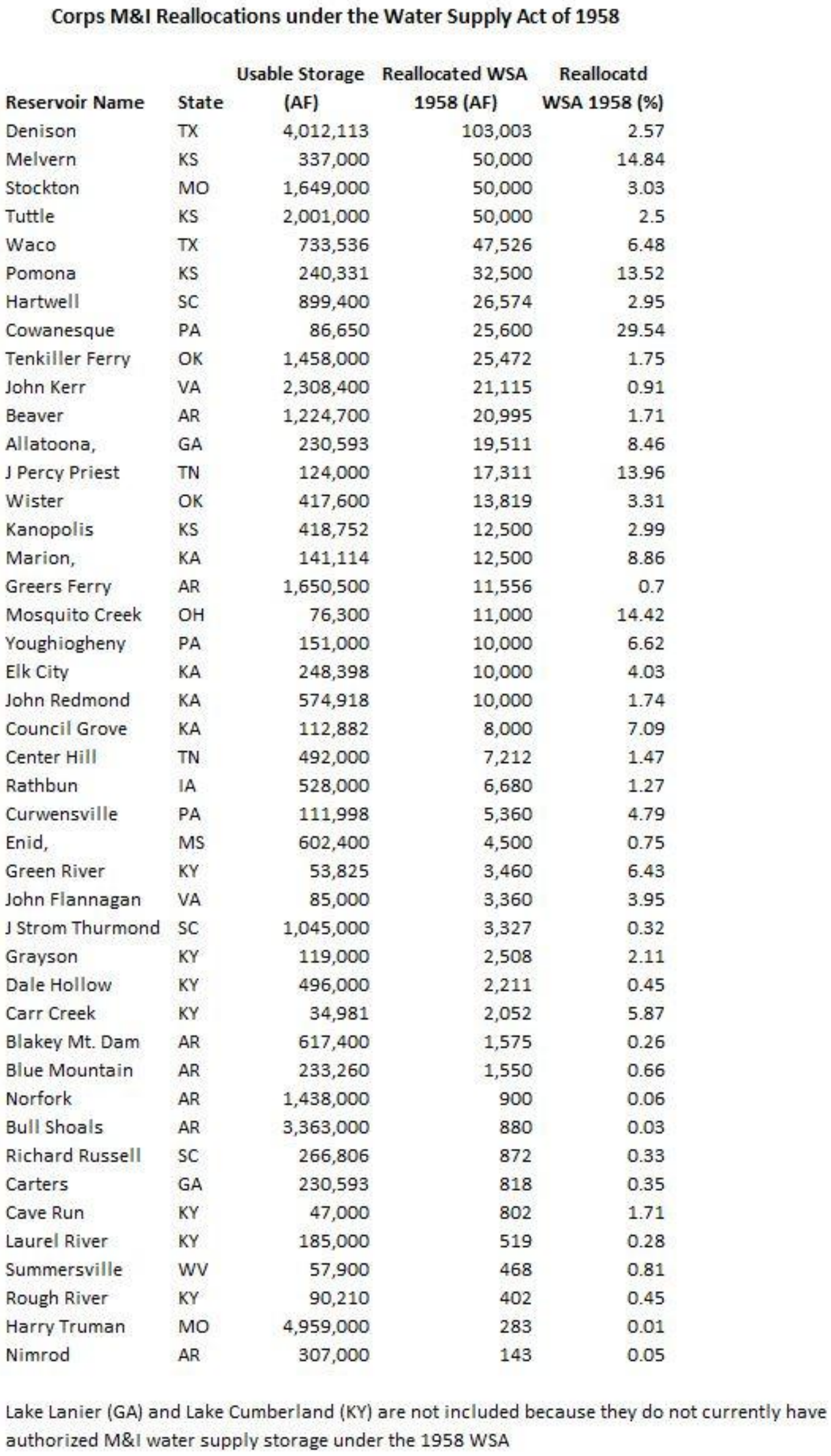
Falls Lake is a dynamic system. Utilization of variable pool elevations through a seasonal guide curve or dynamic event management would reduce the competing demands between flood managers and water supply managers, while increasing the overall resilience in the system. Both variable options improve (decrease) vulnerability to either flood or drought respectively by integrating malleable pools. Static thresholds (guides, pool boundaries or floodplain delineations) are ill equipped to adapt to a variable system.

APPENDIX 1: REALLOCATION

Appendix 1 Table 1. Summary of USACE Reservoir Reallocation Policy by Justin Kirkpatrick and Meg Perry [45]

Reservoir	*State*	*District*	*Years*	*reall. from*	*reall. to*	*volume (AF)*	*% Total*
Bear Creek Reservoir	CO	Omaha	no report as of 1987	Flood	water supply	18,400	31.5
Beaver Lake	AR	SWL	1977-1996	flood	water supply	20,995	1.71
Blakey Mt. Dam Lake Ouachita	AR	MVK	1996	flood	water supply	1,575	0.26
Blue Mountain Lake	AR	SWL	2005	flood	water supply	1,550	0.66
Chatfield Reservoir	CO	Omaha	no report at of 1987	flood	water supply	22,700	9.8
Cowanesque	PA	NAB	1986	flood	water supply	25,600	29.54
Greers Ferry Lake	AR	SWL	1970-2010	flood	water supply	28,125	1.7
Paintsville	KY	LRH	2010	Flood	water supply	3,129	NA
Summersville Lake	WV	LRH	2001	Flood	water supply	468	0.81
Tenkiller Ferry Lake	OK	SWT	64-2007	flood	water supply	25,472	1.75
Wister Lake	OK	SWT	1967-2007	flood	water supply	13,819	3.31
Barren River Lake	KY	Louisville	1965	Flood?	water supply	681	0.084
Granger Lake	TX	Fort Worth	1986	flood?	water supply	65,950	33
Waco Lake	TX	SWF	1984	flood?	water supply	47,526	6.48
Reservoir	*State*	*District*	*Years*	*reall. from*	*reall. to*	*volume (A-F)*	*% Total*
Stockton Lake	MO	NWK	1992	multipurpose	water supply	50,000	3.03
Council Grove Lake	OK	SWT	1996	water quality	water supply	8,000	7.09
Elk City	OK	SWT	1996	water quality	water supply	10,000	4.03
John Redmond	OK	SWT	1996	water quality	water supply	10,000	1.74
John W. Flannagan	VA	LRH	2004	water quality	water supply	3,360	3.95
Marion	OK	SWT	1996	water quality	water supply	12,500	8.86
Melvern Lake	KS	NWK	1994	water quality	water supply	50,000	14.84
Ponoma Lake	KS	NWK	1995	water quality	water supply	32,500	13.52
Tuttle Creek Lake	KS	NWK	1990-1996	water quality	water supply	50,000	2.5
Youghiogheny River Lake	PA		2010	water quality	water supply	10,000	6.62
Youghioghent Lake	PA	LRP	2010	water quality	water supply	2,950	

Appendix 1 Table 2. Summary of USACE Reservoir Reallocations authorized by the Water Supply Act of 1958 [44]



Corps M&I Reallocations under the Water Supply Act of 1958

Reservoir Name	State	Usable Storage (AF)	Reallocated WSA 1958 (AF)	Reallocatd WSA 1958 (%)
Denison	TX	4,012,113	103,003	2.57
Melvern	KS	337,000	50,000	14.84
Stockton	MO	1,649,000	50,000	3.03
Tuttle	KS	2,001,000	50,000	2.5
Waco	TX	733,536	47,526	6.48
Pomona	KS	240,331	32,500	13.52
Hartwell	SC	899,400	26,574	2.95
Cowanesque	PA	86,650	25,600	29.54
Tenkiller Ferry	OK	1,458,000	25,472	1.75
John Kerr	VA	2,308,400	21,115	0.91
Beaver	AR	1,224,700	20,995	1.71
Allatoona,	GA	230,593	19,511	8.46
J Percy Priest	TN	124,000	17,311	13.96
Wister	OK	417,600	13,819	3.31
Kanopolis	KS	418,752	12,500	2.99
Marion,	KA	141,114	12,500	8.86
Greers Ferry	AR	1,650,500	11,556	0.7
Mosquito Creek	OH	76,300	11,000	14.42
Youghiogheny	PA	151,000	10,000	6.62
Elk City	KA	248,398	10,000	4.03
John Redmond	KA	574,918	10,000	1.74
Council Grove	KA	112,882	8,000	7.09
Center Hill	TN	492,000	7,212	1.47
Rathbun	IA	528,000	6,680	1.27
Curwensville	PA	111,998	5,360	4.79
Enid,	MS	602,400	4,500	0.75
Green River	KY	53,825	3,460	6.43
John Flannagan	VA	85,000	3,360	3.95
J Strom Thurmond	SC	1,045,000	3,327	0.32
Grayson	KY	119,000	2,508	2.11
Dale Hollow	KY	496,000	2,211	0.45
Carr Creek	KY	34,981	2,052	5.87
Blakey Mt. Dam	AR	617,400	1,575	0.26
Blue Mountain	AR	233,260	1,550	0.66
Norfork	AR	1,438,000	900	0.06
Bull Shoals	AR	3,363,000	880	0.03
Richard Russell	SC	266,806	872	0.33
Carters	GA	230,593	818	0.35
Cave Run	KY	47,000	802	1.71
Laurel River	KY	185,000	519	0.28
Summersville	WV	57,900	468	0.81
Rough River	KY	90,210	402	0.45
Harry Truman	MO	4,959,000	283	0.01
Nimrod	AR	307,000	143	0.05

Lake Lanier (GA) and Lake Cumberland (KY) are not included because they do not currently have authorized M&I water supply storage under the 1958 WSA

APPENDIX 2: PERMANENT FLOOD CONTROL POOL REALLOCATION

APPENDIX 2.1: REALLOCATION METHODS

A polynomial model comparing total AF stored in the lake with elevation in the reservoir was used to determine the water supply for each additional foot of elevation in the conservation pool. Due to variations in bank slope throughout the reservoir, the amount of AF that could be stored increased exponentially for each additional foot of elevation (Appendix 2 Table 3). All elevations, AF of water stored, and surface areas were provided by USACE Falls Lake website's description of the project and pertinent data [24, 25].

Appendix 2 Table 1. Elevation, AF of water stored, and surface area for each pool in Falls Lake

Pool Name	Pool Elevation (Feet)	Storage Area (AF)	Surface Area (Acres)
Bottom of Sediment Pool	200	0	0
Bottom of Conservation Pool	236.5	25,073	2,600
Top of Conservation Pool	251.5	131,395	12,410
Top of Flood Control Pool	264.8	352,577	21,427
Standard Project Flood	271.3	509,350	26,440
Spillway Design Flood	289.2	1,101,590	39,960

All pool elevations and AF stored were used for this analysis with the exception of the bottom sediment pool which was considered to be an outlier and did not fit the model. Additionally, the trend of the bank slope at the bottom of the lake was not relevant for determining storage space at the top of the conservation pool. The equation used for this analysis was:

$$y = 361.09x^2 - 169{,}440x + 20{,}000{,}000$$

Where y is the stored water in AF and x is the elevation in feet. While this equation had a high r-squared value (r2 = 1), the estimated water storage did not match the observed water storage in each pool. On average, there was 97,597.8 AF of additional storage estimated using this equation. At the top of the conservation pool, there was 94,199.95 AF of additional storage estimated. As this analysis focused only at the surface of the conservation pool, the error associated with the top of the conservation pool was subtracted from total AF to create a more accurate model:

$$y = 361.09x^2 - 169{,}440x + 20{,}000{,}000 - 94{,}199.95$$

APPENDIX 2.2: FLOODPLAIN MANAGEMENT METHODS

The permanent flood pool reallocation option only assessed floodplains in the Upper Neuse Watershed (Wake, Johnston, and part of Wayne Counties). The option was limited to these three counties because we assume that the additional discharge from Falls Lake during storm events would become insignificant past the Wayne-Lenoir County line due to the high amounts of water supplied by multiple tributaries and over land flow within that area.

The cost of increased flood risk in the 100 or 500 year floodplains was quantified using each counties 2013 assessed land and building value for each parcel that fell within the floodplain. Parcel data was provided by each county's Geographic Information Service office [46,47 and 48]. Additionally, the floodplain data was provided by the North Carolina Floodplain Mapping Program [49] and clipped to only the Neuse River channel using an ESRI ArcGIS editing tool. Finally, a non-conflated building footprint layer was used to estimate the location of existing structures in all three counties [50].

A custom tool was designed in Python to run in ESRI ArcGIS to estimate the total cost of land and buildings that fell within the 500 or 100 year floodplains. Parcels were separated into two distinct classes: 1) Parcels where a building fell within the floodplain (Building Parcels), and 2) parcels where only land fell within the floodplain (Land Parcels). The cost of land parcels was calculated as the proportion of land value equal to the percentage of the parcel area that fell within the floodplain. If any portion of a building fell within the floodplain it was determined to be a "building parcel" and the cost was equal to the total assessed value of that parcel. The buildings layer used to inform building location was inaccurate and therefore greater than 15% of the building area must have fell within a given parcel to be classified as a "building parcel". The inaccuracy of the building layer may have introduced error into the cost calculations. These calculations were repeated for both the 100 and 500 year floodplain in each county. A list of land parcels and building parcels were compiled with their associated costs. Additionally, parcels in Wake and Johnston Counties were further separated by land use to inform the type of structures or land that may be within the floodplain. Wayne County did not provide land use codes with their parcel data. In this study the estimated cost of floodplain management (easements, governmental programs, buyouts, etc.) was assumed to be equivalent to the assessed value of the parcels that fell within the floodplain.

APPENDIX 2.3: AVOIDED DAMAGES ESTIMATED FROM FALLS LAKE FLOOD CONTROL

Appendix 2 Table 2. Present value and inflation rate used to estimate the annual prevented flood damages from Falls Lake

Year	Annual Estimated Flood Damages Prevented	Present Value 2012	Inflation Rate
2012	$344,200	$ 356,247	2.10
2011	$456,000	$ 488,479	3.20
2010	$21,232,300	$ 23,540,631	1.60
2009	$3,243,700	$ 3,722,220	(0.40)
2008	$2,651,200	$ 3,148,794	3.80
2007	$3,362,000	$ 4,132,756	2.80
2006	$2,995,000	$ 3,810,476	3.20
2005	$23,600	$ 31,077	3.40
2004	$1,763,400	$ 2,403,333	2.70
2003	$32,814,200	$ 46,287,670	2.30
2002	$0	$ -	1.60
2001	$4,819,000	$ 7,281,840	2.80
2000	$29,400	$ 45,980	3.40
1999	$139,919,200	$ 226,486,443	2.20
1998	$70,656,100	$ 118,373,615	1.60
1997	$5,395,300	$ 9,355,375	2.30
1996	$259,422,000	$ 465,578,321	3.00
1995	$8,777,000	$ 16,303,183	2.80
1994	$10,755,000	$ 20,676,502	2.60
1993	$6,395,000	$ 12,724,700	3.00
1992	$0	$ -	3.00
1991	$3,528,000	$ 7,519,973	4.20
1990	$2,219,000	$ 4,895,368	5.40
1989	$10,545,000	$ 24,077,699	4.80
1988	$0	$ -	4.10
1987	$12,839,000	$ 31,403,662	3.60
1986	$2,367,000	$ 5,992,219	1.90
1985	$419,000	$ 1,097,852	3.60
1984	$2,448,000	$ 6,638,677	4.30
1983	$3,475,000	$ 9,753,608	3.20
	Total Avoided Damages (2012 $)	**$ 1,056,126,699**	**2.94**

APPENDIX 3: SEDIMENT POOL REALLOCATION

Storage transfer amounts from the sedimentation pool to conservation pool were contingent on a number of assumptions, all of which are detailed below.

Appendix 3 Table 1. Pertinent data for sedimentation pool reallocation

Sedimentation pool storage	25,073 AF
Sedimentation pool elevation	200.0 – 236.5
Sedimentation pool surface area	2,600 acres
Drainage area of Neuse River at Falls Dam	770 sq. mi., Watershed section includes Flat River, Little River, Eno River, Neuse River above Falls Dam
Sedimentation Evaluation Plan Timeline	Once every 15 years or after a major flood [4]

APPENDIX 3.1: MODEL ASSUMPTIONS

Chosen sedimentation rate: The rate projections in this report will discard estimates from the 1997 resurvey due to uncertainties in the data, and will instead assume the higher, design-based sedimentation rate of 0.33 AF per year per square mile drainage area, or 254.1 AF per year for the sake of caution.

Sedimentation rate projections: The blue line indicates a continuous, steady decrease in supply based of the design-based sedimentation rate. Higher and lower bounds encapsulate this trendline as future capacity is subject to a number of forces and it is uncommon for rates to remain static. Most of the counties within the Upper Falls Lake watershed are projecting population increases which could result in increased erosion and stormwater runoff. Additionally, rates could increase if climate variability produces severe floods and high-intensty storms within the watershed inducing greater amounts of sediment runoff and channel erosion [51, 52 and 53]. On the other hand, more restrictive watershed and freshwater protection policies may be put in place to counteract the expected rise in development and climate change impacts. Therefore, two other projections were created assuming rate variability with an annual 1% decrease and 1% increase (Figure 7). This provides for sensitivity adjustments to our estimates if sedimentation rates gradually increase or decrease over time

Chosen 25%, 50%, or 90% reallocation amounts: These amounts were partially chosen at random to compare three distinct water supply availabilities and assess how each are expected to decrease over time without dredging. However, these percentages also indicate amounts that would rival or considerably support yields from Little River reservoir. Moreover, they produce quantities within the spectrum of agency discretion for reallocation approval and provide options catering to the various level of risk-taking. For example, choosing the 90% reallocation amount would garner more water supplies, but would require extremely high confidence in sedimentation rate projections.

APPENDIX 4: SEASONAL GUIDE CURVE

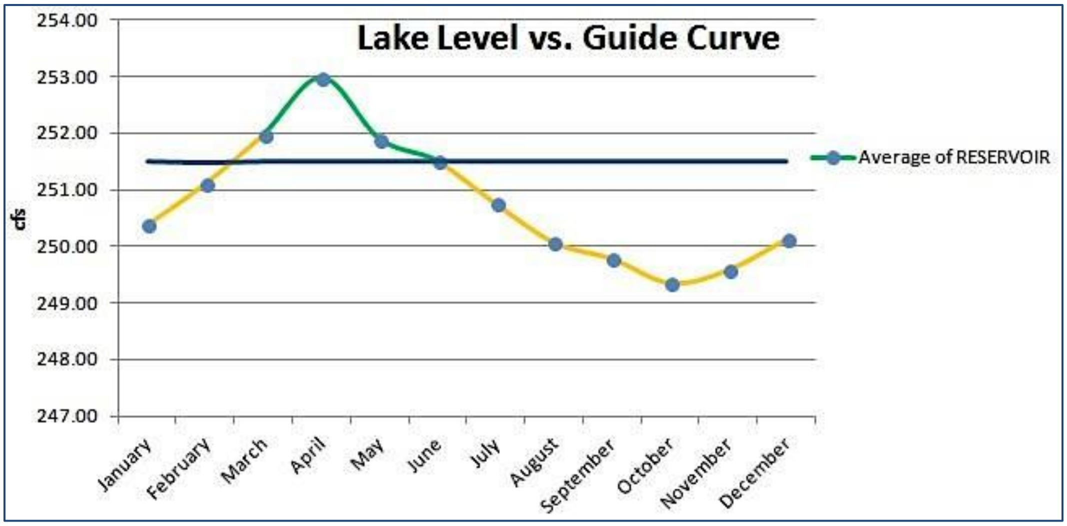
This option presented itself while combing through historical data for Falls Lake reservoir operations [54]. We noted that for the period of record (1983-2012), on average, the lake reservoir level deviated from the guide significantly by season and by month. Might we be able to increase the amount of water available for supply, and potentially increase the safe yield, by decreasing variability between the actual lake surface level and the guide?

APPENDIX 4.1: METHODS

Early analysis found that the lake was chronically over the guide in spring and under in the late summer and early fall (Appendix 4 Figure 1, Appendix 4 Table 1). Our initial hypotheses were as follows:

1. Reservoir operators may be actively managing against severe flood events, as the most significant periods –in time and magnitude below the guide- also correspond to Atlantic hurricane season.

2. Reservoir management became more conservative in its behavior after hurricanes Fran (1996) and Floyd (1999), both events with expected 250-500 year return intervals, depending on the river reach. Clearly these hypotheses are interrelated and testing one would inform the other.

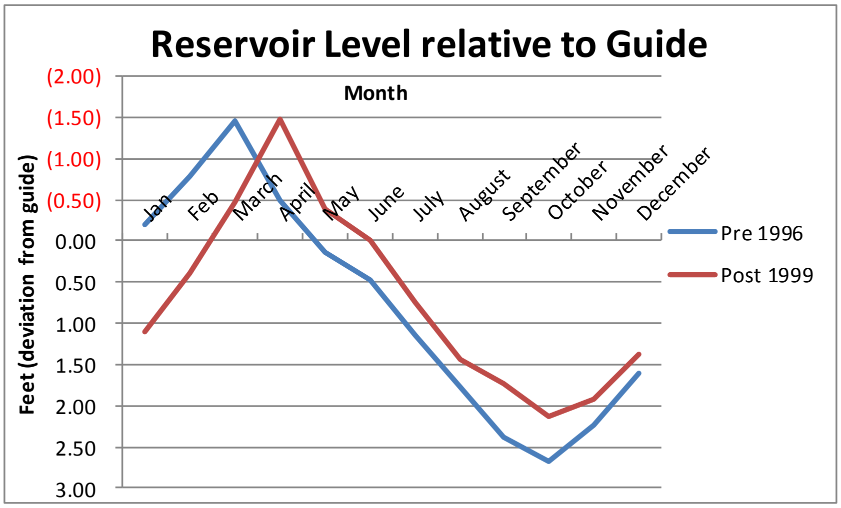


Appendix 4 Figure 1. Guide curve of Falls Lake

Appendix 4 Table 1. Reservoir lake levels (msl) of Falls Lake and difference from guide in feet

Month	Reservoir	Guide	Difference
January	250.39	251.50	(1.11)
February	251.10	251.50	(0.40)
March	251.98	251.50	0.48
April	252.97	251.50	1.47
May	251.89	251.50	0.39
June	251.50	251.50	0.00
July	250.75	251.50	(0.75)
August	250.07	251.50	(1.43)
September	249.77	251.50	(1.73)
October	249.36	251.50	(2.14)
November	249.57	251.50	(1.93)
December	250.13	251.50	(1.37)

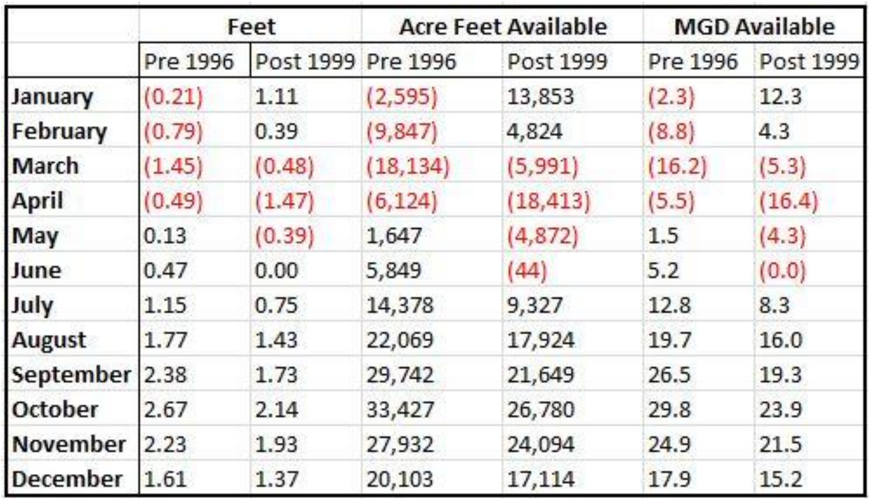
Starting with our second hypothesis, we first compared mean lake surface levels, by month, against the guide in two panels: Pre and post 1996 and 1999. We found it possible that two catastrophic events on the scale of Fran and Floyd, within three years of each other, may have caused a shift in reservoir operations to become more conservative during the months in which hurricanes would be expected to impact the Neuse basin (August-October). Our findings indicate that not only was there no observable shift to more conservative behavior by reservoir operations, it appeared that lake levels post Floyd were higher than pre Fran, opposite of what was to be expected (Appendix 4 Figure 2, Appendix Table 2).



Appendix 4 Figure 2. Actual reservoir Level (pre-1996, post-1999) relative to guide

We observed that the guide curve had been adjusted up from 250.1 msl to 251.5 msl in year 2000. USACE, Wilmington District explained that there had been errors in the original surveying of the reservoir, which translated to inaccuracies in storage elevations and skewed storage capacity, relative to the design of the project. With advances in surveying techniques and precision, the Corps increased the guide to reflect an accurate survey and reservoir design. In addition to raising the guide by 1.4 feet, the elevation of the dam and spillway were increased by 1 foot.

Appendix 4 Table 2. Falls Lake reservoir levels relative to guide pre 1996 and post 1999, by month



	Feet		Acre Feet Available		MGD Available	
	Pre 1996	Post 1999	Pre 1996	Post 1999	Pre 1996	Post 1999
January	(0.21)	1.11	(2,595)	13,853	(2.3)	12.3
February	(0.79)	0.39	(9,847)	4,824	(8.8)	4.3
March	(1.45)	(0.48)	(18,134)	(5,991)	(16.2)	(5.3)
April	(0.49)	(1.47)	(6,124)	(18,413)	(5.5)	(16.4)
May	0.13	(0.39)	1,647	(4,872)	1.5	(4.3)
June	0.47	0.00	5,849	(44)	5.2	(0.0)
July	1.15	0.75	14,378	9,327	12.8	8.3
August	1.77	1.43	22,069	17,924	19.7	16.0
September	2.38	1.73	29,742	21,649	26.5	19.3
October	2.67	2.14	33,427	26,780	29.8	23.9
November	2.23	1.93	27,932	24,094	24.9	21.5
December	1.61	1.37	20,103	17,114	17.9	15.2

Ruling out a behavioral change in management we then asked: is the observed deficit and surplus a visualization of active adaptive management? Or, could the variability in lake level be explained by something else? Not only do the deficits in lake level correspond with hurricane season, they also occur during months of highest demand for municipal, agricultural, and industrial water supply. Perhaps the deficit occurs simply because more water is withdrawn for water supply, both in Falls Lake and upstream, which does not allow the lake level to reach guide during summer months. To answer this question we identified the demand pattern for Raleigh, which would be approximately the same for upstream withdrawals by Durham and Hillsborough. Knowing demand pattern as a ratio of annual average, we tested historic mean inflows by month using our daily Falls Lake data.

APPENDIX 4.2: RESULTS

Our results show high variability of inflows through the year, and more importantly, very low inflows in the summer months, relative to the average of other months (Appendix 4 table 3).

Appendix 4 Table 3. Inflows by month

Month	Mean Inflow (cfs)	Mean All Other Months (cfs)
January	576	516
February	781	500
March	1140	464
April	826	496
May	387	534
June	299	541
July	218	550
August	231	548
September	356	536
October	211	550
November	516	522
December	758	500

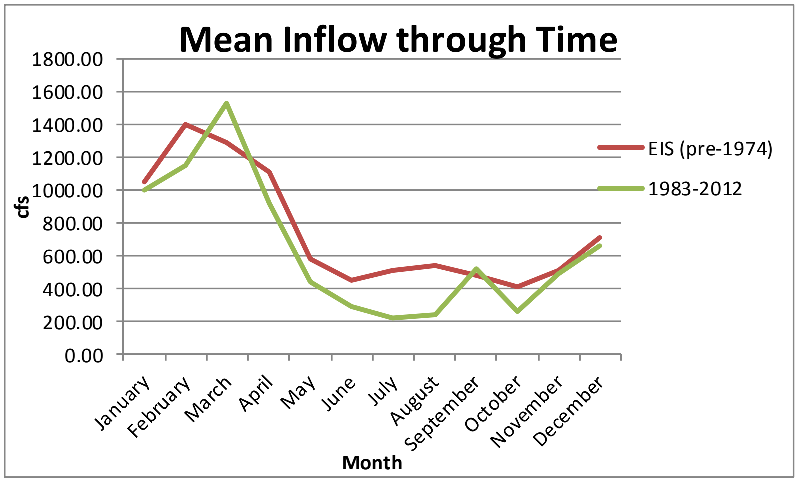
The deviations in both observed inflow and lake level relative to the guide curve show the same pattern: over the guide curve in spring, well under in late summer/early fall. What is even more telling is when observed mean monthly inflows are compared to mean monthly inflows used in the final Environmental Impact Statement [65]. Observed inflows are significantly different than those presented in the EIS. And, the pattern is roughly the same with observed inflow in March well over the historical value (by 237cfs) while June, July and August are under by 161 cfs, 289 cfs and 295 cfs (Appendix 4 Table 4)

Appendix 4 Table 4. Observed and final EIS inflows

Mean Inflow (cfs)			
Month	**1983-2012**	**Pre-1978 (EIS)**	Difference
January	996.82	1054.00	(57.18)
February	1153.85	1397.00	(243.15)
March	1529.91	1292.00	237.91
April	924.21	1108.00	(183.79)
May	441.66	584.00	(142.34)
June	287.83	449.00	(161.17)
July	223.93	513.00	(289.07)
August	240.62	536.00	(295.38)
September	520.94	483.00	37.94
October	256.5	412.00	(155.50)
November	493.63	512.00	(18.37)
December	655.83	707.00	(51.17)

APPENDIX 4.3: DISCUSSION

The upper Neuse basin has experienced tremendous growth since the writing of the EIS. It is possible that both land cover change and increased withdrawals for municipal and agricultural use have altered inflow patterns, especially in late summer months where inflows have decreased the most. However, If inflows varied only from development and/or demand upstream we would expect to see a more uniform pattern in the change of inflow (i.e. decreases would be approximately equal throughout the year). And, we would not expect to see overages in a period of dryer climatic conditions. This leads us to



Appendix 4 Figure 3. Changes in inflow pattern

believe that the changes in inflow pattern since the time of the EIS is attributable to a combination of demand increase and climate variability.

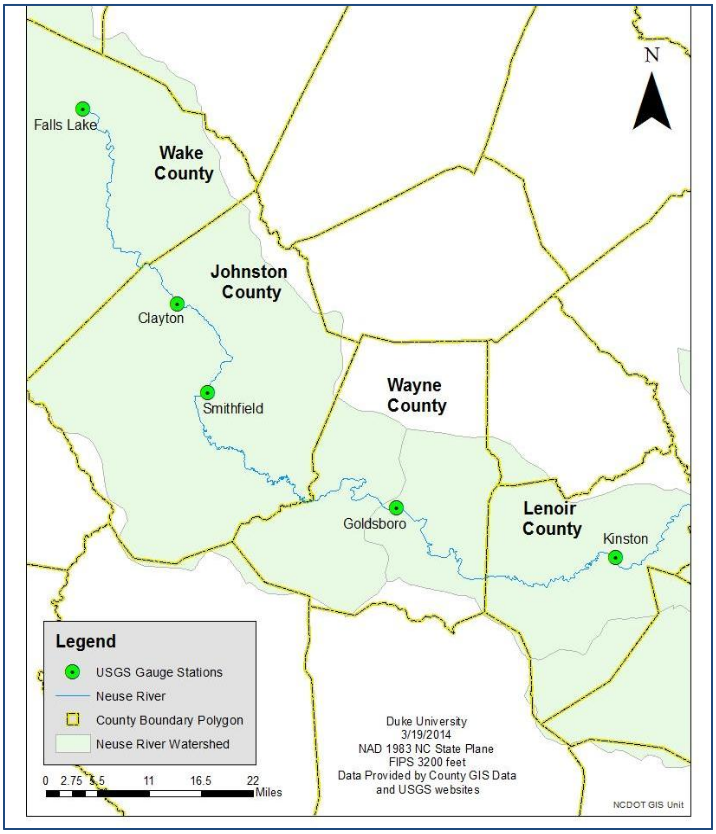
If we accept that inflow patterns have changed, and that the change is due to a mixture of upstream influences, natural variability, climate and land cover change, we see an opportunity to build in seasonality to the guide curve. Through our analysis of reservoir levels through the year, observed inflows and consideration of flood risk, it seems plausible to increase the guide curve at the end of the spring by 1 to 2 feet. In doing so the reservoir level at the end of the summer (October 1) after heavy drawdown would be close to the permanent guide of 251.5 msl, instead of being nearly two feet under. This additional 1-2 feet of storage translates to enough raw water supply (14,000-20,000 AF) to meet Raleigh's highest demand months while ensuring that the lake will be drawn down to 251.5 msl (or lower) by the period of most significant hurricane risk (after September 1).

While this opportunity does not achieve a permanent new supply of water for the city of Raleigh, it can allow for the public utility to stretch the existing supply from Falls Lake further, and for longer, and postpone a new reservoir. The city is concerned about 50 year projections which will demand a new supply source; but again, the utility is concerned about meeting an increase in peak demand. If a seasonal increase in the guide can achieve that end at a time when demand is roughly 20% higher than the annualized average, then there appears to be enough supply to meet demand requirements for the remainder of each year, for several years to come.

APPENDIX 5: DYNAMIC EVENT MANAGEMENT

APPENDIX 5.1: METHODS

The dynamic event management option requires Falls Lake to release a flood pulse before a large storm event in order to lower reservoir levels back to an elevation that can accommodate the increased flow. However, Falls Lake would need to stop releasing water long enough before the storm so that the Neuse River discharge could fall back to base flow from Falls Lake to Kinston. An analysis to determine the amount of time a flood pulse of varying magnitude released form Falls Lake was used to derive the appropriate amount of time Falls Lake should not be discharging water before a storm event. Average monthly discharge and average monthly gauge height was collected from five USGS gauging stations along the Neuse River at Neuse River near Falls (USGS Gauge ID: 02087183), Neuse River near Clayton (USGS Gauge ID: 02087500), Neuse River at Smithfield (USGS Gauge ID: 02087570), Neuse River near Goldsboro (USGS Gauge ID: 02089000), and Neuse River at Kinston (USGS Gauge ID: 02089500; Appendix 5 Figure 1) [55, 56].



Appendix 5 Figure 1. Project extent for the dynamic event management option with USGS gauging station

Distance between each gauge station was determined using a nearest neighbor network analysis in ESRI ArcGIS. Coordinates from each USGS gauge station site were used for the locations along the stream. The stream network was derived from the USGS National Hydrologic Network (NHD 2014). Average channel velocity and discharge data was provided by the USGS gauge station field measurements (NWIS 2014). Average channel velocity was graphed against its associated discharge at each location to determine their relationship. Channel velocity had a logarithmic relationship to channel discharge. The equations for each site had a mean R-squared greater than 0.8 (with the exception of the Smithfield gauge which had an R-squared of 0.73). Therefore, the velocity for each gauge was calculated by including each average monthly discharge plus an additional discharge of 8,000 cfs, 7,000 cfs, or 6,000 cfs to represent an additional release from Falls Lake. It was assumed that the velocity between gauges on average remained constant. The time it takes for a given discharge to reach Kinston from Falls Lake was determined by averaging the two velocity measurements from each consecutive gauge station and dividing the distance between those gauges by that number. This provided the number of seconds it would take a given discharge to travel between two consecutive gauges. This analysis was repeated for the average discharge of every month. Additionally, this analysis was repeated after adding 8000, 7000, and 6000 CFS to every discharge measurement to represent a high release period from Falls Lake.

Our estimates are based on the assumption that there is no decay rate/peak attenuation in our pulse of 8,000 cfs, 7,000 cfs, or 6,000 cfs. In reality the peak would lengthen, the amplitude would fall, and the 'tail' of the pulse would take longer to pass through to Kinston than the peak.

Clayton is the area most sensitive to flood and therefore our constraint on the dynamic option. Stage of 9 to 13 feet, or approximately 5,400 to 9,100 cfs, represents minor flooding. 13 to 16 feet and 9,100-11,800 cfs represents moderate flooding. Major flooding is greater than 16 feet and 11,800 cfs.

APPENDIX 5.2: RESULTS

On average Falls Lake would need to forecast large storm events four days before they reach the Neuse Basin (Appendix 5 Table 1). This would allow enough time to release the full additional 13.7 mgd (15,350 AF) stored in the reservoir and provide enough time for that discharge to pass Kinston, NC. These times are based on the assumption that the stream is at base flow prior to any storm.

Appendix 5 Table 1. Total time necessary for Falls Lake to release 13.7 mgd and allow flood to reach Kinston, NC at varying discharge rates

Discharge (CFS)	Time Necessary to Draw Down 13.7 mgd (days)	Average Time for Flood Peak to Reach Kinston (days)	Total Time (days)
8,000	0.97	2.91	3.87
7,000	1.11	2.97	4.07
6,000	1.29	3.04	4.33

APPENDIX 6

APPENDIX 6.1: FLOODPLAIN MANAGEMENT, MITIGATION STRATEGIES AND FEDERAL FLOOD HAZARD POLICY - CASE STUDIES, EVALUATIONS AND LOCAL FINDINGS

Our opportunity for permanent flood pool reallocation is predicated on progressive flood mitigation strategies inside the 500 year floodplain. We have identified the specific parcels, land uses and accompanying values for the Upper Neuse from Falls Lake dam to the edge of Johnston County. And, we have estimated to a certain degree the costs and benefits (avoided future costs) associated with removing persons and property from flood hazard areas. We now wish to discuss in depth the chronology of floodplain management and floodplain development for historical perspective; and contrast competing interests and often perverse incentives, between the federal government and local communities. Lastly, we will highlight where wide-scale mitigation activities have achieved mutually beneficial outcomes and net benefits to federal taxpayers, state governments, local governments, private landowners and citizen interest groups.

APPENDIX 6.2: HISTORY OF NATIONAL FLOOD POLICY

National flood mitigation strategy can be broadly defined by three sequential phases. Phase I: Structural flood control. Phase II: Regulation and insurance. Phase III: Mitigation by removal, relocation and avoided development [57]. Structural Flood Control grew from a combination of 1. Large flood events on the Mississippi in 1917 and 1927 gave way to the Flood Control Act of 1936 and 2. Growth in urban population centers and agriculture in the West. From approximately 1917 to 1965 large levee systems and colossal flood control dams were constructed to protect cities like New Orleans and Sacramento. Unfortunately, structurally engineered solutions increased flood risk in some areas by constricting the flood way and encouraging development on the plain just behind or below levees and dams, which increased both the number of individuals and structures and property values in flood prone areas.

In response to increased risk, structural solutions gave way to regulation aimed to encourage smart local land use planning; and insurance through the National Flood insurance Program (NFIP) to shift costs from the federal government to local governments and private landowners. Though arguably successful in addressing future development and re-distributing some risk, Phase II did nothing to address the glut of development that had already taken place in the floodplain, particularly in urban areas; and insurance policies through NFIP were/are underwritten and subsidized by the federal government. Phase II ended after the Midwest floods of 1992 when the Mitigation Directorate and Hazard Mitigation Grant Programs (HMGP) was created. Phase III consists of a variety of programs and activities developed to flood proof, relocate, remove and/or acquire private lands and structures in flood hazard areas. At its heart, the current phase of flood mitigation consists of pro-active withdrawal from the flood plain to avoid future costs of damage and loss of life and property. Though some mitigation activities may only take place after a disaster, others can be executed at any time and generally carry a 75/25 cost share between the federal government and the state and/or local government.

APPENDIX 6.3: CASE STUDIES IN MITIGATION

Available mitigation programs fall in to two categories: proactive (pre-disaster) and reactive (post-disaster). FEMA has programs for both categories; however reactive, post-disaster programs are utilized the most. What follows is a discussion of case studies using the HMGP (in conjunction with other federal assistance e.g. HUD grants). Though our proposal (Permanent Flood Control Pool Reallocation by way of land acquisition) would utilize pro-active programs such as Pre-Disaster Mitigation (PDM), Flood Mitigation Assistance (FMA) and Community Rating System (CRS) activities 520/530, the application process, cost shares and activity is nearly identical to reactive acquisition and buyout programs. Additionally, the post-disaster mitigation programs may still be viewed as pro-active in the sense that removal after one event mitigates risk for a subsequent or event.

Greenville, North Carolina: Initiated after hurricane Floyd in 1999, the city utilized the HMGP to purchase over 450 homes for $24.5 million [57]. Being home to Eastern Carolina University there were a large number of rental properties and landlords who were hesitant to sell as they did not want to lose rental income. The state of North Carolina stepped in to provide supplemental funding, on top of the buyout money, to cover the gap between floodplain property value (on more marginal land) and market price (rents) of the new neighborhoods.

Kinston, North Carolina: Initiated after hurricane Floyd in 1999 when the Neuse rose to twice its flood stage elevation (28ft). Two sewage treatment plants flooded into the river during this 500 year flood. The HMGP was used to acquire 700 homes in the buyout. Many property owners chose to participate in 1999 after suffering through their second 500 year event within three years (hurricane Fran, 1996). Just upstream in neighboring Wayne County, NC over 200 properties were acquired and around 300 families relocated after the double whammy of Fran and Floyd [5].

Grand Forks, ND: Spring floods on the Red River after a wet winter with large blizzards saw the river crest at 54 ft. an astonishing 26ft above flood stage. 800 properties were acquired for $13 million with the HMGP. Flood damages totaled $2 billion. The community also received $171 million from HUD. After experiencing their own great flood, officials from Grand Forks helped in North Carolina in 1999 urging local officials to use buyouts in Greenville & Rocky Mount [57].

San Antonio, TX: During this 500 year event in 1998, 20" of rain fell in 24 hours. For comparison San Antonio's annual average rainfall is 30". Buyouts included 400 structures for approximately $10 million and the acquired properties were turned into parks, recreation areas and green spaces [57].

Nashville, TN: The city and surrounding metropolitan area received 10-20 inches of precipitation in 48 hours, equivalent to a 1,000 year event. The structural flood control measures, including an Army Corps flood control dam, were insufficient resulting in 11,000 damaged structures, 26 flood related deaths and an estimated $2 billion in losses. The city developed a diverse strategy of flood damage reduction alternatives, including home buyouts, inside of the 500 year floodplain [58].

The City of Nashville and Tennessee Emergency Management Agency (TEMA) worked with FEMA to acquire structures lying in the flood way (more than 530 damaged) and others inside the 100 year floodplain (another 2,500 damaged structures) [59]. Greater than 300 residential structures were identified by Metro Water Services (Nashville) for buyout by 2013, with more than 200 already purchased and removed (AWRA Proactive Flood and Drought Management paper). With FEMA covering 75% of the buyout cost, Metro Water Services covered 12.5% and TEMA covered the final 12.5%.

Easton, PA: This historic city at the confluence of the Lehigh and Delaware Rivers became the first municipality in the country to adopt a 500 year floodplain standard. Successive floods in 2004, 2005 and 2006 of greater than 100 year return intervals shifted the city's approach to floodplain management and flood damage mitigation. The new 500 year standard, in conjunction with zoning and development ordinances, stormwater management and park construction allowed the city to manage a larger percentage of the built environment in its historic downtown as well as the most vulnerable areas previously outside of the managed floodplain. Roughly $400 million was invested over seven years, half of which were made with public funds, partly through municipal bonds [58].

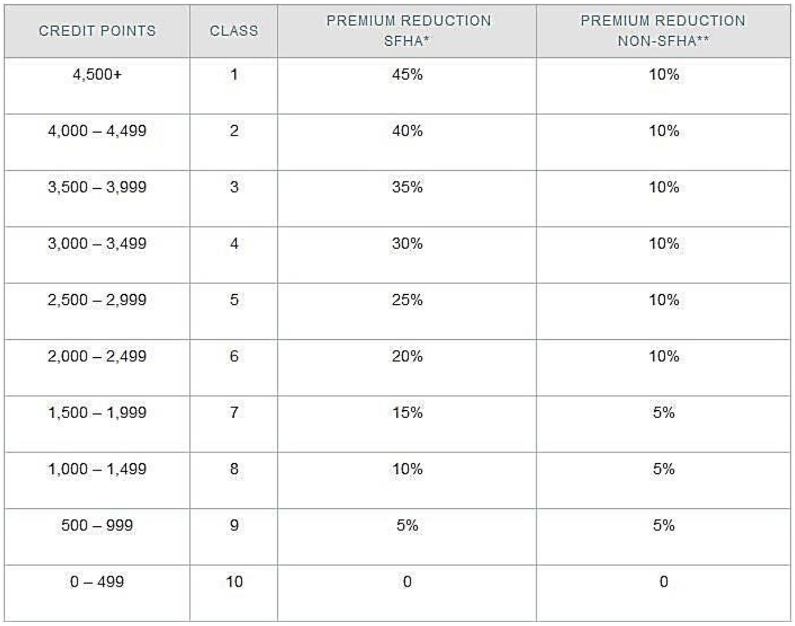
APPENDIX 6.4: FLOODPLAIN MANAGEMENT IN THE NEUSE BASIN – WAKE, JOHNSTON, WAYNE COUNTIES AND THEIR MUNICIPALITIES.

Discussions were held with floodplain and flood mitigation managers in Wake and Wayne counties, the City of Raleigh, the North Carolina Office of Emergency Management and FEMA Region IV. Several takeaways from our conversations at the local level follow. First, buyouts have been used in Wake and Wayne counties several times over the past 15 years. Though both individuals whom we spoke with were unsure of the specific program utilized for the buyouts, we assume the HMGP was used as acquisitions discussed were made after flooding events. Wayne County for example purchased over 200 properties, relocating more than 300 families from marginal lands after hurricane Floyd in 1999 [60]. Similarly the City of Raleigh in Wake County has used mitigation buyouts frequently including commercial properties and apartment complexes predominantly in the Crabtree Creek watershed of north Raleigh. In conversation with the city, four or five properties have been acquired within the last year, though it is unknown what program was used [61].

Second, the counties participate in FEMA's Community Rating System (CRS) program. CRS generates insurance premium discounts to communities that exceed NFIP requirements. Activities like higher regulatory standards (430), retrofitting (530), open space preservation (420) and preparedness activities (600) generate credits to the community. The amount of credits a community generates dictates its Class within CRS. Class 1 is the highest achievable, as credit generating activities generate premium reductions to policyholders both inside and outside the Special Flood Hazard Area (1% Rule/100 year event). Raleigh is Class 7 and Wayne County Class 6 [60, 61]. See the table below for detail on CRS classes.

The local governments adhere to standards above and beyond FEMA NFIP and CRS obligations through local ordinances and requirements. Both Raleigh and Wayne County mandate a two foot freeboard, which is the amount of additional height of a structure above the base flood elevation (BSE).

Appendix 6 Table 1. Credit points earned by NFIP CRS community class [62]



CREDIT POINTS	CLASS	PREMIUM REDUCTION SFHA*	PREMIUM REDUCTION NON-SFHA**
4,500+	1	45%	10%
4,000 – 4,499	2	40%	10%
3,500 – 3,999	3	35%	10%
3,000 – 3,499	4	30%	10%
2,500 – 2,999	5	25%	10%
2,000 – 2,499	6	20%	10%
1,500 – 1,999	7	15%	5%
1,000 – 1,499	8	10%	5%
500 – 999	9	5%	5%
0 – 499	10	0	0

In addition to freeboarding (additional elevation above base flood height), land uses are restricted inside the floodplain where sub-divisions and mobile home parks are not allowed. The official from Wayne County noted that pre-1950 most of these flood prone parcels were large and generally contained a single farm house, built on the highest ground, which minimized flood risk [58]. However as land was sub-divided and many homes and apartments built on increasingly marginal land risk and associated costs rose tremendously.

Third, repetitive loss properties are several but do not appear to be substantial. The city of Raleigh claimed to have "many" repetitive loss properties but it was not quantified [59]. Wayne County stated they have "two or three" repetitive loss properties- that is a property with two or more claims payments of greater than $1,000 in any rolling 10 year period [58, 61]. Repetitive loss properties overall represent the largest payout of the NFIP, some $3.5 billion since inception in 1965 [64].

Lastly, one fact that complicates, delays and discourages local governments from participating in FEMA buyout programs is the requirement that acquired properties remain as open space in perpetuity. Particularly for rural economies like those found in Wayne and Johnston Counties, the loss of dozens of properties from the tax rolls denies local governments revenue from already limited sources. A couple possible solutions come to mind. As these lands are already of relatively low value, an allowance from FEMA to the county or municipality in the form of a stream of foregone tax revenue payments could be made to sweeten the pot and lessen the blow. Wayne County proposed that these lands once acquired, be made available for private purchase with land use restricted to certain forms of agriculture [58].

APPENDIX 6.5: EVALUATION OF THE NFIP (FROM AIR NFIP FINAL REPORT) [64]

Problems with NFIP:

1. Repetitive Loss Properties
2. Subsidized insurance
3. Grandfathered properties (Pre-NFIP/1965)

Shortcomings of NFIP:

1. No tools with teeth for protection of floodplain or restoration
2. Reduced federal support
3. Not ridding nation of flood prone properties at the rate or level that it should. Most flood prone properties still lack insurance.

Problems with Mitigation:

1. More utilization of reactive than pro-active programs
2. Funding/Cost Share
3. Loss of tax base by requiring open space in perpetuity (ties in to 1 and 2)

APPENDIX 6.6: OVERALL BENEFITS OF A PRO-ACTIVE FLOODPLAIN STRATEGY:

1. Savings to federal taxpayers
2. Proper valuation of NFIP premiums
3. Removal of recurring loss properties
4. Removal of human from danger in flood zone
5. Avoided Future Costs
6. Floodway connectivity
7. Adaptive Capacity- reduces exposure, reduces vulnerability, reduces risk in a dynamic system

THE MATRIX

The Matrix below represents a brief synopsis of the four main alternatives introduced in the report, along with Little River Reservoir. Key features of interest compare each option, details of which are provided in the corresponding report section or appendix.

Rating Criteria	**Flood Pool Reallocation**	**Seasonal Guide Curve**	**Dynamic Management**	**Sedimentation Reallocation**	**Little River Reservoir**
Water Supply	13.7 - 23 mgd*	11 - 25 mgd	13.7 mgd	5.5 - 20 mgd	13.7 mgd
Costs	$100s millions	~$5.8 million*	~$5.8 million*	~$5.8 million*	>$350 million
Risks	Increased Flood Risk, Political Changes, CBA	Inaccuracy in Current Guide Curve	Increased Downstream Flood Risk	Future Increase in Sedimentation Rates	Not Meeting projected demand
Project Impacts	Flood Control (major)	Flood Control (minimal)	Flood Control/ Water Supply	None	N/A
Co-Benefits	Avoided Flood Damages	None	Flood Pulses	None	Recreation
Time Frame	3 – 15 years	3 - ? years	3 - ? years	5 - 8 years	6-10 years
Feasibility	Low	Medium	Low-Medium	High	N/A

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